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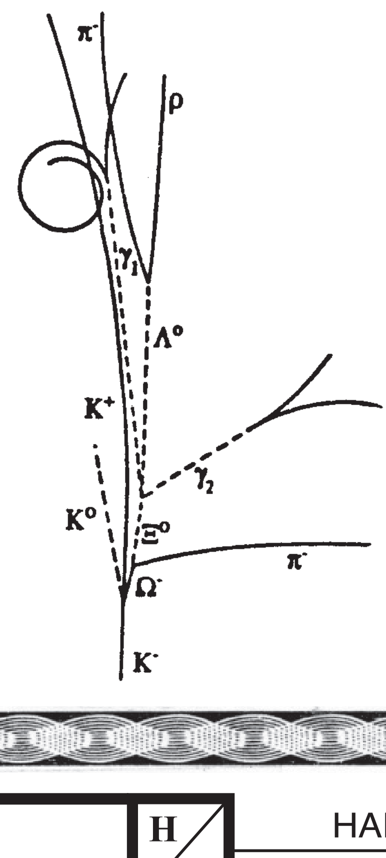

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ELECTROMAGNETIC SPINOR AND WAVE FUNCTIONS IN MINKOWSKI SPACETIME

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Abstract

We show how generate the electromagnetic spinor verifying the Maxwell equations in vacuum; we also exhibit the Whittaker and Bateman wave functions and their connection with electromagnetic fields in Minkowski geometry.

Keywords: Maxwell spinor, Riemann-Silberstein vector, Maxwell equations, Wave functions, Quaternions.

All electromagnetic information is contained in the Faraday's skew-symmetric tensor [1-3]:

$$(\mathrm{F}^{\mu\nu}) = \begin{pmatrix} 0 & -\mathrm{E}_1 & -\mathrm{E}_2 & -\mathrm{E}_3 \\ \mathrm{E}_1 & 0 & -c\mathrm{B}_3 & c\mathrm{B}_2 \\ \mathrm{E}_2 & c\mathrm{B}_3 & 0 & -c\mathrm{B}_1 \\ \mathrm{E}_3 & -c\mathrm{B}_2 & c\mathrm{B}_1 & 0 \end{pmatrix}, \tag{1}$$

where $\vec{\mathrm{E}} = (\mathrm{E}_1, \mathrm{E}_2, \mathrm{E}_3)$ and $\vec{\mathrm{B}} = (\mathrm{B}_1, \mathrm{B}_2, \mathrm{B}_3)$ are the electric and magnetic fields expressed in the MKS system of units, respectively, verifying the Maxwell equations in empty spacetime:

$$\vec{\nabla} \cdot \vec{\mathrm{E}} = \vec{\nabla} \cdot \vec{\mathrm{B}} = 0, \qquad \vec{\nabla} \times \vec{\mathrm{E}} = -\frac{\partial \vec{\mathrm{B}}}{\partial t}, \qquad \vec{\nabla} \times \vec{\mathrm{B}} = \frac{1}{c^2}\frac{\partial \vec{\mathrm{E}}}{\partial t}. \tag{2}$$

If we introduce the Riemann [4]-Silberstein [5, 6] complex vector (thus named by Bialynicki-Birula [7]) [8]:

$$\vec{\mathrm{F}} = c\,\vec{\mathrm{B}} + i\,\vec{\mathrm{E}}, \tag{3}$$

then (2) are equivalent to two complex equations [9]:

$$\vec{\nabla} \cdot \vec{\mathrm{F}} = 0, \qquad \vec{\nabla} \times \vec{\mathrm{F}} + \frac{i}{c}\frac{\partial}{\partial t}\vec{\mathrm{F}} = \vec{0}, \tag{4}$$

and the corresponding spinorial form is given by [10-14]:

$$\partial_{B\dot{C}}\, \varphi^{AB} = 0, \tag{5}$$

involving the symmetric Maxwell spinor. It is clear that, without boundary conditions, the equations (5) have many solutions, thus it is important to have a method to construct them.

On the other hand, we know that a unitary quaternion [15-17] generates rotations in three and four dimensions [18-20], but, what happens with a null quaternion? Here we consider the following case:

$$\mathbf{A} = -\sin\tau - i\,\mathbf{I} + \cos\tau\,\mathbf{K} \quad \therefore \quad \mathbf{A}\bar{\mathbf{A}} = (\sin\tau)^2 + i^2 + (\cos\tau)^2 = 0, \quad (6)$$

with its associated 2x2 complex matrix:

$$\widetilde{M} = \begin{pmatrix} ie^{i\tau} & 1 \\ 1 & -ie^{-i\tau} \end{pmatrix}. \quad (7)$$

Now the interesting result is that (7) allows construct solutions for (5), in fact:

$$(\varphi^{AB}) = \frac{1}{2}\int_0^{2\pi} \widetilde{M}\; G(u,v,\tau)\, d\tau, \qquad u = x\cos\tau + y\sin\tau + i\,z,$$
$$v = x\sin\tau - y\cos\tau + c\,t, \quad (8)$$

where G is an arbitrary function of its arguments; hence (8) is a factory to elaborate solutions for the Maxwell equations in vacuum, that is:

$$\varphi^{11} = \frac{i}{2}\int_0^{2\pi} e^{i\tau}\, G\, d\tau, \qquad \varphi^{12} = \varphi^{21} = \frac{1}{2}\int_0^{2\pi} G\, d\tau,$$
$$\varphi^{22} = -\frac{i}{2}\int_0^{2\pi} e^{-i\tau}\, G\, d\tau\,. \quad (9)$$

We have the expressions for the spinor covariant derivative [12]:

$$\partial_{1\dot{1}} = \frac{1}{\sqrt{2}}\left(\frac{\partial}{c\,\partial t} + \frac{\partial}{\partial z}\right), \quad \partial_{2\dot{1}} = \overline{\partial_{1\dot{2}}} = \frac{1}{\sqrt{2}}\left(\frac{\partial}{\partial x} + i\,\frac{\partial}{\partial y}\right),$$
$$\partial_{2\dot{2}} = \frac{1}{\sqrt{2}}\left(\frac{\partial}{c\,\partial t} - \frac{\partial}{\partial z}\right), \quad (10)$$

then it is simple to prove the relations:

$$\partial_{1\dot{1}}G = \frac{1}{\sqrt{2}}\left(\frac{\partial G}{\partial v} + i\,\frac{\partial G}{\partial u}\right) = i\,e^{-i\tau}\,\partial_{2\dot{1}}G\,,\ \partial_{2\dot{2}}G = \frac{1}{\sqrt{2}}\left(\frac{\partial G}{\partial v} - i\,\frac{\partial G}{\partial u}\right) =$$
$$-i\,e^{i\tau}\,\partial_{1\dot{2}}G\,, \quad (11)$$

thus with (9) and (11) is immediate verify (5), *q.e.d.*

The components of the Riemann-Silberstein complex vector (3) are given by:

$$F_1 = i(\varphi^{22} - \varphi^{11}) = \int_0^{2\pi} G \cos\tau \, d\tau, \qquad F_2 = -(\varphi^{22} + \varphi^{11}) = \int_0^{2\pi} G \sin\tau \, d\tau, \;\; F_3 = 2i\varphi^{12} = i\int_0^{2\pi} G \, d\tau,$$

in agreement with the result of Bateman [9]:

$$\vec{\mathrm{F}} = \int_0^{2\pi} G(x\cos\tau + y\sin\tau + i\,z, x\sin\tau - y\cos\tau + c\,t, \tau)\,\vec{\mathrm{R}}\,d\tau,$$
$$\vec{\mathrm{R}} = (\cos\tau, \sin\tau, i). \qquad (12)$$

We have the valuable theorem of I. Robinson and J. L. Synge [2, 22-25]:

"Every solution of the vacuum Maxwell equations in Minkowski spacetime can be written in terms of two real wave functions and a constant real bivector", (13)

and the corresponding Faraday tensor is given by the expression:

$$\mathrm{F}_{\mu\nu} = (\mathrm{H}_\mu{}^\lambda\, \mathrm{U}_{,\lambda} + {}^*\mathrm{H}_\mu{}^\lambda\, \mathrm{V}_{,\lambda})_{,\nu} - (\mathrm{H}_\nu{}^\lambda\, \mathrm{U}_{,\lambda} + {}^*\mathrm{H}_\nu{}^\lambda\, \mathrm{V}_{,\lambda})_{,\mu}\,, \qquad (14)$$

where $\Box\mathrm{U} = \Box\mathrm{V} = 0$ and ${}^*\mathrm{H}_{\mu\nu}$ is the dual of the constant skew-symmetric tensor $\mathrm{H}_{\mu\nu}$.

The first person to suggest that a vacuum electromagnetic field could be constructed from only two real wave functions was Whittaker [23, 24, 26-29]: He showed explicitly that the Liénard-Wiechert field of an accelerating point charge could be derived from a pair of wave functions, and he calculated these functions. With the constant tensor:

$$(\mathrm{H}^{\mu\nu}) = \begin{pmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 \end{pmatrix} \quad \therefore \quad ({}^*\mathrm{H}^{\mu\nu}) = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}, \qquad (15)$$

the relations (1) and (14) imply the following expressions of Whittaker [26]:

$$E_1 = \frac{\partial^2 U}{\partial x\,\partial z} + \frac{1}{c}\frac{\partial^2 V}{\partial y\,\partial t}, \qquad E_2 = \frac{\partial^2 U}{\partial y\,\partial z} - \frac{1}{c}\frac{\partial^2 V}{\partial x\,\partial t}, \qquad E_3 = \frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 U}{\partial y^2}, \tag{16}$$

$$c\,B_1 = -\frac{\partial^2 V}{\partial x\,\partial z} + \frac{1}{c}\frac{\partial^2 U}{\partial y\,\partial t}, \quad c\,B_2 = -\frac{\partial^2 V}{\partial y\,\partial z} - \frac{1}{c}\frac{\partial^2 U}{\partial x\,\partial t}, \quad c\,B_3 = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2}.$$

Now we need a systematic method to construct the scalar wave functions U and V, in fact [26]:

$$U = \int_0^{\pi}\int_0^{2\pi} f(x\sin u\,\cos v + y\sin u\sin v + z\cos u + c\,t, u, v)\,du\,dv,$$

$$V = \int_0^{\pi}\int_0^{2\pi} g(x\sin u\,\cos v + y\sin u\sin v + z\cos u + c\,t, u, v)\,du\,dv, \tag{17}$$

where f and g are arbitrary functions of their arguments. Bateman [9, 30] showed an alternative approach to find wave functions in four dimensions:

$$W = \int_0^{2\pi} G(x\cos\tau + y\sin\tau + i\,z, x\sin\tau - y\cos\tau + c\,t, \tau)\,d\tau, \tag{18}$$

being G an arbitrary function. Finally, we comment that Whittaker [9, 31] proved that the function:

$$w = \int_0^{2\pi} h(z + i\,x\cos\alpha + i\,y\sin\alpha, \alpha)\,d\alpha, \tag{19}$$

for h an arbitrary function, satisfies the Laplace equation $\nabla^2 w = 0$.

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THE SYSTEM OF EQUATIONS DESCRIBING 4 GENERATIONS WITH THE SYMMETRY GROUP $SU(3)$ X $SU(2)_L$ X $U(1)$*

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Abstract

The system of 16-component equations including two equations of the Bethe-Salpeter kind (without an interaction) and two additional conditions are considered. It is shown that the group of the initial symmetry is $SU(3)_C \times SU(2)_L \times U(1)$. The symmetry group is established as the consequence of the field equations; $SU(2)$ should be chiral, the color space has the signature $(++-)$. The structure of permissible multiplets of the group coincides with the one postulated in the $SU(3)_C \times SU(2)_L$-model of strong and electroweak interactions excluding the possible existence of the additional $SU(2)_R$-singlet in a generation.

*This paper (in Russian) was deposited in VINITY 19.12.1988 as VINITI No 8842-B88; it was an important stage in the development of my model of the composite fundamental fermions (see hep-th/0207210). I have translated it in English (small corrections are made) to do more available. It was presented at The 3rd International Conference on Symmetry, 8-13 Aug 2021, virtual.

1 Introduction

The lepton and quark sectors of the model of strong and electroweak interactions based on the group $SU(3)_C \times SU(2)_L \times U(1)$ [1], if one does not take into account differences relatively to $SU(3)_C$, differ insignificantly - one singlet of $SU(2)_R$ is introduced in the lepton sector, and the two singlets in the quark one. If results of measurements of the neutrino mass [2] are confirmed, the simplest way to modify the model to get the non-zero neutrino mass is the introduction of the second $SU(2)_R$ singlet in the lepton sector. It is shown in this paper that the model of field of the two-component fermions admitting the existence of four generations of the same type has namely such the structure of multiplets and such the group of the initial symmetry of its solutions. It is important that the types of the symmetry group and of its admitted multiplets are consequences of the model which can be established by the analysis of the field equations. The minimum number of generations cannot be arbitrary, too. The representation about a color of a field state may be connected in the model with the certain inversions affecting internal and external coordinates of the composite fermion. So, it is possible that the similar model of the field of fermions may be used to construct the general description of the fundamental particles and their interactions.

The considered model by zero masses of the components may be interpreted in two ways: as the non-local field theory based on the use of the two-point wave function in the 4-space-time or as the local field theory in the eight-dimensional pseudo-euclidian space with two time axis, and besides the additional coordinates have clear physical interpretation: the ones are the coordinates of the relative position of the composite system's components. It is known that the geometrical description of fields and their interactions in spaces of a dimension greater than 4 permits to consider jointly gravi-electro-weak and gravi-electro-strong interactions in 7-dimensional space with one time [3], and the possibility of the simple interpretation of the additional dimensions in the 8-space seems to be essential.

2 The 16-component field equations of the two-component fermions

Let us use the Dirac way to introduce the field equations for ψ starting from the classical equations of the connection of the energies E, E^1, E^2 and of the momenta $\mathbf{p}, \mathbf{p}^1, \mathbf{p}^2$ of the composite system and its components:

$$E = E^1 + E^2, \tag{1}$$

$$\mathbf{p} = \mathbf{p}^1 + \mathbf{p}^2, \tag{2}$$

where $E^i = (m^{i2} + \mathbf{p}^{i2})^{0.5}$. At first we linearize the non-linear (relatively p^{ik}) equation (1), and after that we replace the classical energies and momenta by their operators. With Eq.(1) we juxtapose the linear equation ($c = h = 1$):

$$i\partial\psi/\partial t = (\beta_1 m^1 + \alpha_{1k} p^{1k} + \beta_2 m^2 + \alpha_{2k} p^{2k})\psi, \tag{3}$$

where t is the time, p^{1k}, p^{2k} are the operators of the constituents momenta, β_i, α_{ik} are matrices, $k = 1, 2, 3$. It may be shown that matrices of the dimension greater than 8×8 are needed to satisfy the conformity principle. The dimension 16×16 is sufficient to construct the matrices with the following algebra containing commutators [ ] and anticommutators { }:

$$\begin{gathered} \{\alpha_{ik}, \alpha_{il}\} = 2\delta_{kl}, \{\alpha_{il}, \beta_i\} = 0, \\ [\beta_i, \beta_j] = [\alpha_{ik}, \beta_j] = [\alpha_{ik}, \alpha_{jl}] = 0,\ \beta_i^2 = I_{16},\ i \neq j, \end{gathered} \tag{4}$$

there is not summation on i.

These relations are executed for the following matrix presentation:

$$\begin{gathered} \beta_1 = I_2 \times \sigma_3 \times I_4,\ \beta_2 = \sigma_3 \times \sigma_3 \times I_4, \\ \alpha_{1k} = \sigma_1 \times \sigma_1 \times I_2 \times \sigma_k^{'},\ \alpha_{2k} = \sigma_1 \times I_2 \times \sigma_k^{''} \times I_2, \end{gathered} \tag{5}$$

where σ_k are the Pauli matrices, $\sigma_k^{'}$, $\sigma_k^{''}$ are two transpositions of them, for example: $\sigma_k^{'} = \sigma_k^{''} = \sigma_k$. Eq. (3) has the same form as the Bethe-Salpeter equation [4] which is used for the description of such composite systems as mesons.

For the momentum operators it will be naturally to postulate instead Eq. (2) the following connection:

$$p^k\psi = p^{1k}\psi + p^{2k}\psi, \tag{6}$$

where p^k is the operator of the system momentum, ψ is the 16-component vector. If we introduce the operators of the component energies E^1, E^2, the Eq. (3) will have the same view ($E \equiv i\partial/\partial t$):

$$E\psi = E^1\psi + E^2\psi, \tag{7}$$

i.e. the equations of motion of the components are:

$$E^i\psi = \alpha_{ik}p^{ik}\psi + \beta_i m^i\psi, \tag{8}$$

there is not summation on i. If $x_{1\mu}$, $x_{1\mu}$ are the coordinates of the first and second components, $\psi = \psi(x_{1\mu}, x_{1\mu})$, then Eqs. (6,7) in the form: $p^\mu\psi = p^{1\mu}\psi + p^{2\mu}\psi$ can be understood as a transition in the eight-dimensional pseudo-euclidian space from the coordinates $x_{1\mu}$, $x_{2\mu}$ to the new coordinates x_μ, y_μ, where x_μ are the coordinates of the system center of inertia, and y_μ are still not defined. In the space of the operators $p^{1\mu}$, $p^{2\mu}$ by such the transition we can define the operators $\pi_\mu \equiv i\partial/\partial y^\mu$ to be independent of p^μ as:

$$\pi_\mu\psi \equiv p_{1\mu}\psi - p_{2\mu}\psi. \tag{9}$$

Then from Eq. (8) besides Eq. (3) we get the equation independent of it:

$$\pi^0\psi = (\beta_1 m^1 - \beta_2 m^2 + \alpha_{1k}p^{1k} - \alpha_{2k}p^{2k})\psi. \tag{10}$$

Eqs. (3, 10) contain the terms: $\alpha_{1k}p^{1k}\psi \pm \alpha_{2k}p^{2k}\psi \equiv 1/2((\alpha_{1k} \pm \alpha_{2k})p^k\psi + (\alpha_{1k} \mp \alpha_{2k})\pi^k\psi)$, distinguished by the replacement $p^k\psi \leftrightarrow \pi^k\psi$. Such the matrices A_k exist that the additional condition to be accepted:

$$\alpha_{1k}p^{1k}\psi + \alpha_{2k}p^{2k}\psi = A_k p^k\psi, \tag{11}$$

and its consequence (due to the noted symmetry):

$$\alpha_{1k}p^{1k}\psi - \alpha_{2k}p^{2k}\psi = A_k\pi^k\psi \tag{12}$$

lead to the split of the 16-component Eqs. (3, 10) into the four Dirac equations for some sets of four components of ψ. Let us accept Eq. (11) as a postulate; we can choose A_k as: $A_k = I_2 \times \sigma_1 \times \sigma_k \times I_2$. Now we can rewrite Eqs. (3, 10) as:

$$E\psi = (\beta_1 m^1 + \beta_2 m^2)\psi + A_k p^k \psi, \tag{13}$$

$$\pi^0 \psi = (\beta_1 m^1 - \beta_2 m^2)\psi + A_k \pi^k \psi, \tag{14}$$

where $\psi = \psi(x_\mu, y_\mu)$, and Eqs. (11, 12) taking into account Eqs. (6, 7) as:

$$(A_k - \alpha_{1k})(p^k + \pi^k)\psi = 0, \tag{15}$$

$$(A_k - \alpha_{2k})(p^k - \pi^k)\psi = 0. \tag{16}$$

By the transition from Eq. (8) to Eqs. (13,14) the conditions (15,16) provide the compatibility of these system of equations for the function ψ given in the different coordinate spaces. These conditions do not contain evidently derivatives with respect to time, to be like the condition on a wave function for particles with spin 3/2, when field equations are written in the Rarita-Schwinger form [5]. Eqs. (13-16) give us the model of the two-component system without interactions describing four sets of fermions in the physical space with the coordinates x_μ which will be named generations.

3 Discrete and continues symmetries of the model

Let us consider the symmetries of the model for the case $m^1 = m^2 = 0$. The structure of the matrices is such that the following sets of components of ψ obey the Dirac equations:

$$\psi_1, \psi_3, \psi_5, \psi_7;\ \ \psi_2, \psi_4, \psi_6, \psi_8;\ \ \psi_9, \psi_{11}, \psi_{13}, \psi_{15};\ \ \psi_{10}, \psi_{12}, \psi_{14}, \psi_{16}.$$

Let us introduce left and right components of these four-component spinors ψ': $\psi'_L = 1/2(1-\gamma_5)\psi'$, $\psi'_R = 1/2(1+\gamma_5)\psi'$; their components of the view $1/2(\psi_k \pm \psi_n)$ we shall write shortly as $k \pm n$, where $(+)$ relates to the right components, $(-)$ relates to the left ones. The existence of pairs of solutions

of Eqs. (13,14) leads to the $SU(2)$ symmetry of the model. The analysis of the conditions (15) and (16) shows that namely the ones define the structure of $SU(2)$ multiplets. These conditions put on the following restrictions: 1) doublets and singlets of $SU(2)_L$, as well as $SU(2)_R$, cannot exist together; 2) if ψ^A and ψ^B are two different solutions, then their components separately may form only singlets; 3) the first (second) component of doublets can be formed only from components of one solution; 4) it is possible to form up to 4 doublets of one of groups $SU(2)_L$ or $SU(2)_R$ (it depends on a variant of the model), moreover all doublets are transformed on the interwoven group presentations (i.e. the transformation of one doublet should be accompanied by the same transformation of other doublets), and up to 8 singlets of another $SU(2)$.

Before to prove these propositions let us explain what is mentioned as "model variants". The algebra (4) admits the sign change for any matrix of the chosen presentation. Let $\varepsilon_{ik} = \pm I$ be multipliers for α_{ik} by this change, $\alpha_{ik} \to \varepsilon_{ik}\alpha_{ik}$ (there is not summation by i, k). It turns out that by $\varepsilon_{1k}\varepsilon_{2k} = +I$ for any k only the $SU(2)_R$ doublets are possible, and by $\varepsilon_{1k}\varepsilon_{2k} = -I$ only the $SU(2)_L$ doublets are possible.

To prove the given propositions let us rewrite (15) and (16) in components:

$$D_1\varphi_1 = 0, \; D_2\varphi_2 = 0, \tag{17}$$

where the operators $D_i \equiv (p^{i1}, -p^{i1}, ip^{i2}, -ip^{i2}, p^{i3}, -p^{i3})$, where $p^{i\mu} = p^{i\mu}(p^\mu, \pi^\mu)$, and the matrices φ_1, φ_2 have the view:

$$\left| \begin{array}{cccccccc}
3\pm7 & 4\pm8 & 1\pm5 & 2\pm6 & 11\pm15 & 12\pm16 & 9\pm13 & 10\pm14 \\
10\pm14 & 9\pm13 & 12\pm16 & 11\pm15 & 2\pm6 & 1\pm5 & 4\pm8 & 3\pm7 \\
10\pm14 & -(9\pm13) & 1\pm5 & 2\pm6 & 2\pm6 & -(1\pm5) & 9\pm13 & 10\pm14 \\
3\pm7 & 4\pm8 & -(12\pm16) & 11\pm15 & 11\pm15 & (12\pm16) & -(4\pm8) & 3\pm7 \\
1\pm5 & 2\pm6 & -(11\pm15) & 12\pm16 & 9\pm13 & 10\pm14 & -(3\pm7) & 4\pm8 \\
9\pm13 & -(10\pm14) & 3\pm7 & 4\pm8 & 1\pm5 & -(2\pm6) & 11\pm15 & 12\pm16
\end{array} \right|$$

$$\begin{vmatrix} \pm(3\pm7) & \pm(4\pm8) & \pm(1\pm5) & \pm(2\pm6) & \pm(11\pm15) & \pm(12\pm16) & \pm(9\pm13) & \pm(10\pm14) \\ 11\pm15 & 12\pm16 & 9\pm13 & 10\pm14 & 3\pm7 & 4\pm8 & 1\pm5 & 2\pm6 \\ 11\pm15 & 12\pm16 & \pm(1\pm5) & \pm(2\pm6) & 3\pm7 & 4\pm8 & \pm(9\pm13) & \pm(10\pm14) \\ \pm(3\pm7) & \pm(4\pm8) & 9\pm13 & 10\pm14 & \pm(11\pm15) & \pm(12\pm16) & 1\pm5 & 2\pm6 \\ \pm(1\pm5) & \pm(2\pm6) & 11\pm15 & 12\pm16 & \pm(9\pm13) & \pm(10\pm14) & 3\pm7 & 4\pm8 \\ 9\pm13 & 10\pm14 & \pm(3\pm7) & \pm(4\pm8) & 1\pm5 & 2\pm6 & \pm(11\pm15) & \pm(12\pm16) \end{vmatrix}$$

If ψ is transformed under the action of generators of $SU(2)_L$ or $SU(2)_R$, all columns of the matrices φ_1, φ_2 should be saved excluding their rearrangements. Let ψ^A, ψ^B be solutions of Eqs. (13,14). The matrices φ_i are such that components of ψ^A (or ψ^B) cannot be the first and the second components of the doublet because by the $SU(2)$ transformations it would lead to the change of some columns of φ_i, i.e. from ψ^A (ψ^B) only singlets may be constructed. The matrix φ_1 allows the single correspondence besides of identical between components of ψ^A and ψ^B: $\psi^B = U\psi^A$, where $U = \sigma_1 \times I_8$, i.e.

$$\begin{matrix} (1+5)^A & (3+7)^A & (2+6)^A & (4+8)^A & (9+13)^A & (11+15)^A & (10+14) & (12+16)^A \\ (9+13)^B & (11+15)^B & (10+14)^B & (12+16)^B & (1+5)^B & (3+7)^B & (2+6)^B & 4+8)^B \end{matrix} \tag{18}$$

That gives 4 possible doublets of $SU(2)_L$ or $SU(2)_R$, moreover the component placement in columns of φ_1 is such that the same transform should be carried out above all four sets of components. If we suggest that one of these possible doublets can be replaced on two singlets then components of other possible doublets should be or zero or the pairs of singlets of the corresponding $SU(2)$.

By virtue of the Dirac equation for $R-$ and $L-$components (only by $m_1 = m_2 = 0$) Eq. (17) can be transformed to the view ($E^i \equiv p^{i0}$):

$$D_1^{'}\varphi_1^{'} = 0, \; D_2^{'}\varphi_2^{'} = 0, \tag{19}$$

where the operators $D_i^{'} \equiv (p^{i1}, -ip^{i2}, p^{i3}, p^{i0})$, and the matrices $\varphi_1^{'}$, $\varphi_2^{'}$ have the view:

$$\begin{vmatrix} 10\pm14 & 9\pm13 & 12\pm16 & 11\pm15 & 2\pm6 & 1\pm5 & 4\pm8 & 3\pm7 \\ 10\pm14 & -(9\pm13) & 12\pm16 & -(11\pm15) & 2\pm6 & -(1\pm5) & 4\pm8 & -(3\pm7) \\ 9\pm13 & -(10\pm14) & 11\pm15 & -(12\pm16) & 1\pm5 & -(2\pm6) & 3\pm7 & -(4\pm8) \\ \pm(1\pm5) & \pm(2\pm6) & \pm(3\pm7) & \pm(4\pm8) & \pm(9\pm13) & \pm(10\pm14) & \pm(11\pm15) & \pm(12\pm16) \end{vmatrix},$$

$$\begin{vmatrix} 3\pm7 & 4\pm8 & 1\pm5 & 2\pm6 & 11\pm15 & 12\pm16 & 9\pm13 & 10\pm14 \\ 3\pm7 & 4\pm8 & -(1\pm5) & -(2\pm6) & 11\pm15 & 12\pm16 & -(9\pm13) & -(10\pm14) \\ 1\pm5 & 2\pm6 & -(3\pm7) & -(4\pm8) & 9\pm13 & 10\pm14 & -(11\pm15) & -(12\pm16) \\ 9\pm13 & 10\pm14 & 11\pm15 & 12\pm16 & 1\pm5 & 2\pm6 & 3\pm7 & 4\pm8 \end{vmatrix},$$

that is equivalent in this case to the record of Eq. (8) via components.

The inversion $(x,y) \to (x,-y)$ transfers $D_1' \leftrightarrow D_2'$, $\psi(x,y) \to \psi'(x,-y) = u\psi(x,y)$. By that we have:

$$D_1'\varphi_1'[\psi(x,y)] \to D_2'\varphi_1''[u\psi(x,y)],$$

$$D_2'\varphi_2'[\psi(x,y)] \to D_1'\varphi_2''[u\psi(x,y)],$$

i.e. Eq. (19) will be invariant under this transformation if $\varphi_1'' = \varphi_2'$, $\varphi_2'' = \varphi_1'$. The matrices φ_1', φ_2' can be transferred one into another transforming ψ but only for ψ_L or ψ_R: the transform exist for that components to whom the same signs correspond in the bottom rows of φ_1', φ_2'. Then $\varphi_1''(V\psi_{R\vee L}) = \varphi_2'(\psi_{R\vee L})$, $\varphi_2''(V\psi_{R\vee L}) = \varphi_1'(\psi_{R\vee L})$, V is the matrix, $V = V^{-1}$, $R \vee L$ means "R or L". Only for that type of components the existence of the $SU(2)$ doublets is permitted. For the given presentation (5) $SU(2)_R$ doublets exist, $\varepsilon_{1k}\varepsilon_{2k} = +I$; $SU(2)_L$ doublets are permitted by $\varepsilon_{1k}\varepsilon_{2k} = -I$, i.e. after the change of signs of α_{1k} or α_{2k}.

The group $SU(2)$ is not an only symmetry group of the model. Unlike φ_1, φ_1' admits 8 types of solutions distinguishing by the transposition of the ψ components; all of them, taking into account the transform $\psi \to V\psi$, are allowed by φ_2', too. These eight solutions are splitted in two subsets of the considered type of ψ^A and $\psi^B = U\psi^A$, i.e. four types of doublets of some $\psi_{R\vee L}$ are admitted. Let us show these possible solutions as the substitutions skipping solution indices (their second part can be get by the transform $\psi \to U\psi$):

$$\begin{matrix} 1\pm5 & 3\pm7 & 2\pm6 & 4\pm8 & 9\pm13 & 11\pm15 & 10\pm14 & 12\pm16 \\ 3\pm7 & 9\pm13 & 4\pm8 & 10\pm14 & 11\pm15 & 1\pm5 & 12\pm16 & 2\pm6 \\ 1\pm5 & 11\pm15 & 2\pm6 & 12\pm16 & 9\pm13 & 3\pm7 & 10\pm14 & 4\pm8 \\ 3\pm7 & 1\pm5 & 4\pm8 & 2\pm6 & 11\pm15 & 9\pm13 & 12\pm16 & 10\pm14 \end{matrix} \qquad (20)$$

Writing them as: $\psi, U_1\psi, U_2\psi, U_3\psi$, where U_k are the transposition matrices, we have the following algebra for U_k an U:

$$\begin{aligned} U_1U_2U_3 = U_2U_3U_1 = U_3U_1U_2 = U, \\ U_1U_3U_2 = U_2U_1U_3 = U_3U_2U_1 = I, \\ U_2U_1 = U_3,\ U_1U_3 = U_2,\ U_2U_3 = U_1, \\ U_1U_2 = UU_3,\ U_3U_1 = UU_2,\ U_3U_2 = UU_1, \\ U_1^2 = U,\ U_2^2 = U_3^2 = I,\ [U, U_k] = 0. \end{aligned} \tag{21}$$

By (21), all solutions are splitted into the two classes if we identify $\psi \sim U\psi$: the ones having only one of three "properties" being an analog of three "colors" of quarks (it is $U_k\psi$), and having all three "properties" (it is ψ). So, we may interpret in this way the concept of "color" for the composite system. By the additional requirement of the conservation of the norm $\psi^+\psi$ for every class of solutions, $SU(3)_C \times SU(2)$ will be the global symmetry group, the chiral properties of solutions are already discussed. The solutions $U_k\psi,\ k = 1,2,3$, form the $SU(3)$ triplets, while ψ and $U\psi$ form its singlets and the doublet of one of $SU(2)_{R\vee L}$, $U_k\psi$ and $UU_k\psi$ will be the doublets of the last, too. Let us note that $[V, U_k] \neq 0,\ [V, U] = 0$.

The discrete group of 16×16 matrices: $S = \{I, U_k, UU_k, U | k = 1,2,3\}$ forms the representation of the groups of transformations of the coordinates (x, y) by 8×8 matrices $S = \{I, u_k, uu_k, u\}$ and of the coordinates $(x_{1\mu}, x_{2\mu})$ by 8×8 matrices $S' = \{I, u'_k, u'u'_k, u'\}$ with the same algebra (21). To reconstruct the last group by s, let us use the following reduction method. Note that U represents the inversion $(x, y) \to (x, -y)$, and the last is equivalent to the display $(x_{1\mu}, x_{2\mu}) \to (x_{2\mu}, x_{1\mu})$. Let us introduce the continuous numbering of the coordinates $x_{i\mu}$: $z_{\alpha+1} = x_{1\alpha}$, $z_{\alpha+5} = x_{2\alpha}$, $\alpha = 0,1,2,3$, their transforms will be written as a substitutions (we will write k instead of z_k). The matrix u' corresponding to the inversion we get if to assign numbers $1, 2, ..., 8$ to the spinors components in the first raw of (18), and to identify the substitution of these numbers by (18) with u':

$$u' = \left| \begin{array}{cccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ 5 & 6 & 7 & 8 & 1 & 2 & 3 & 4 \end{array} \right|.$$

This reduction method lets to write all matrices $u_k{}'$ by the substitutions

(20):

$$
u_1{}' = \begin{vmatrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ 2 & 5 & 4 & 7 & 6 & 1 & 8 & 3 \end{vmatrix},
$$

$$
u_2{}' = \begin{vmatrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ 1 & 6 & 3 & 8 & 5 & 2 & 7 & 4 \end{vmatrix},
$$

$$
u_3{}' = \begin{vmatrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ 2 & 1 & 4 & 3 & 6 & 5 & 8 & 7 \end{vmatrix}.
$$

By them one can reconstruct the matrices u_k of the group s taking into account relations of $x_\mu,\ y_\mu$ with $x_{1\mu},\ x_{2\mu}$:

$$
u_1 = \begin{vmatrix} x_0 & x_1 & x_2 & x_3 & y_0 & y_1 & y_2 & y_3 \\ x_1 & x_0 & x_3 & x_2 & y_1 & -y_0 & y_3 & -y_2 \end{vmatrix},
$$

$$
u_2 = \begin{vmatrix} x_0 & x_1 & x_2 & x_3 & y_0 & y_1 & y_2 & y_3 \\ x_0 & x_1 & x_2 & x_3 & y_0 & -y_1 & y_2 & -y_3 \end{vmatrix},
$$

$$
u_3 = \begin{vmatrix} x_0 & x_1 & x_2 & x_3 & y_0 & y_1 & y_2 & y_3 \\ x_1 & x_0 & x_3 & x_2 & y_1 & y_0 & y_3 & y_2 \end{vmatrix}.
$$

Two of these transforms affect the sector of coordinates x_μ, and all of them affect the sector of y_μ; Eqs. (13 - 16) are invariant under such the transforms. From the geometrical point of view, the sets $\{U_k\},\ \{u_k\},\ \{u_k^{'}\}$ are the generatrix sets of some algebras which are homomorphic to the Clifford algebra $C(2,1)$ corresponding to the 3-dimensional color space with the signature $(++-)$ [3]. The discrete groups S, s, $s^{'}$ are isomorphic to the dihedron group D_4 [6].

4 Conclusion[1]

Now it is obvious that the second $SU(2)_R$ singlet in the lepton sector is necessary to explain nonzero neutrino masses. It is shown here that at least three puzzling features of the standard model: the existence of a few generations, the specific symmetry group, and the necessity to use its interwoven

[1] It is added in this version of 2020.

representations may originate from the composite nature of the fundamental fermions. The author has not proven that the similar model with three generations cannot exist. It is very important that the continues symmetries of the model in the four-dimensional space may be caused by its discrete symmetries in some higher-dimensional space. Some further development of this model can be found in the author's later paper [7].

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INTRODUCTION TO A NEW INTERPRETATION OF RELATIVITY IN A COMPLEX SPACE

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Abstract

In Einstein's Relativity, the 4th-dimensional space-time manifold considers future-pointing and past-pointing matter. An interpretation of relativity, both in the special-relativistic domain and in the general-relativistic domain, inside a complex $\mathbb{C}^4$ space, is here proposed in order to face the matter that, in Einstein's approach, time is understood as a dimension through which a given physical object can move in both directions: into past and into future, leading to the existence of positive and negative space-time intervals, which seems logically inconsistent. In particular, an approach to general relativity inside a pseudo-complex space is suggested, which provides an extension of the standard general relativity and a justification of its results in terms of fundamental energy density fluctuations of a three-dimensional quantum vacuum and can be discriminated from general relativity in situations which are near the size of a black hole.

Keywords: special relativity, general relativity, complex space, three-dimensional quantum vacuum, energy density fluctuations.

1. Introduction

In special relativity, the four-vector is introduced in order to unify space-time coordinates x, y, z, and t into a single entity. The length of this four-vector, called the space-time interval, is shown to be invariant, which means the same for all inertial observers.

In general relativity, the four-vector measuring the "length" of a particle worldline is parametrized by its proper time and can be positive or negative and depends on the direction of motion in future or in past:

$$d\tau = \pm\sqrt{dx^{\mu}dx_{\mu}} \qquad (1),$$

where τ is proper time [1]. Equation (1) implies that solutions with a positive or a negative sign are equally valid. This implies that, in general relativity, velocities can be backwards in time or future-pointing four-vectors.

In light of the equivalence principle, the laws of physics are the same for future-pointing (τ^{+}) and past-pointing (τ^{-}) observers, and this means that the terms "past" and "future" turn out to do not have an absolute meaning, they only have a meaning relative to the reference frame of the observer. By following [1], one can thus show that past-pointing four-vectors cannot be dealt with consistently in general relativity unless one accepts that the stress-energy tensor created/observed by matter going backwards in time inevitably has a sign opposite to the stress-energy tensor created/observed by matter going forward in time. In the light of these conjectures, one can conclude that time reversed matter moves on a different branch with respect to future pointing matter. Both branches, which interact through repulsive gravity, are connected by sharing the same stress-energy tensor up to a change in sign. On a large scale, equal amounts of future-pointing and past-pointing matter should be expected. This means that our experience of time as always going forwards is due to the separation of past-pointing matter and future-pointing matter by gravity (a spontaneous local symmetry breaking): the mutual repulsion between future-pointing matter and past-pointing matter could result in voids which generate a dark gravitational halo around galaxies.

By considering the energy density E measured by an observer at some point of a material object

$$E = T^{\mu\nu}u_{\mu}u_{\nu} \quad (2)$$

one finds immediately that stress-energy tensor $T^{\mu\nu}$ changes sign when the observer has its four-velocity u_μ reversed, thus leading to a different geometry of space-time for a past-pointing observer with respect to a future pointing observer. As a consequence, one has contributions to the stress-energy tensor characterized by a opposite sign for past-pointing matter and future-pointing matter, thus leading to two different metrics, and geodesics, for general relativity. In the light of this consideration, a paradox therefore emerges that when either the source or the observer is represented by a past-pointing four vector, the stress-energy tensor has the opposite sign than the conventional one, and consequently a second, different metric, which affects the geodesic curves in a non-trivial way, is required in order to assure consistency.

In this paper, in order to avoid the impasse generated by the consideration of negative solutions of the equation (1) of proper time, which leads to a different expression – of opposite sign – for the stress-energy tensor and thus to the consideration of a different metric tensor (which means a violation of the principle of uniqueness of free fall, in the sense that, if one reverses the proper time, one obtains a reversal of the four-velocity, and thus a change in the state of motion), we suggest an alternative approach where the fundamental arena of processes is a complex space which is ultimately linked with a microscopic quantum vacuum condensate. The paper is structured as follows. In section 2, we will introduce our interpretation of special relativity inside a complex $\mathbb{C}^4$ space. In section 3 we will develop a version of general relativity in a complex space which can provide an extension of general relativity able to take account of strong gravitational fields. In section 4 we will analyse some predictions of our model of general relativity in a complex space. Finally, in section 5 we will summarize the main results of our model, by putting in evidence some issues that will have to be addressed.

2. Replacement of the Minkowski manifold $\mathbb{R}^4$ with the complex manifold $\mathbb{C}^4$ in special relativity

In the space-time model $\mathbb{R}^4$ the fourth coordinate X_4 is imaginary, X_1, X_2, X_3 are real coordinates. In the complex $\mathbb{C}^4$ space, the 4th coordinate Z_4 is a complex coordinate as the other three coordinates Z_1, Z_2, Z_3, every point of it has complex coordinates:

$$z_i = x_i + i\,y_i \qquad (3),$$

where (x_i, y_i) (i = 1,2,3,4). In $\mathbb{C}^4$ space-time is the duration of a motion of a given physical object. $\mathbb{C}^4$ is time-invariant in the sense that time is not its dimension [2].

As the authors have shown in [3, 4], the Einstein space-time arena $\mathbb{R}^4$ can be replaced by a three-dimensional (3D) Euclidean space where time has a different ontological status with respect to the coordinates of space in the sense that must be considered merely as a mathematical quantity measuring the numerical order of material changes. In this background, one considers Galilean transformations between the spatial coordinates X, Y, Z and X', Y', Z' of two inertial observers

$$\begin{aligned} X' &= X - v \cdot \tau \\ Y' &= Y \\ Z' &= Z \end{aligned} \qquad (4)$$

(where v is the velocity of the moving observer O' measured by the stationary observer O and τ is the proper time of the observer O), and Selleri's formalism [5, 6] as regards the transformation of the rate of clocks:

$$\tau' = \sqrt{1 - \frac{v^2}{c^2}} \cdot \tau \quad (5)$$

which shows clearly that the speed of the moving clock is not related to the spatial coordinates but depends only of the speed v of the moving observer. In light of equations (4) and (5), in our theory the standard Einstein postulates of special relativity can be therefore replaced by the following ones [3, 4]:

1. The velocity of light has the same value in all directions and in all inertial systems (postulate of the invariance of the velocity of light in the vacuum).
2. The fundamental arena of physical processes is a 3D Euclid space where time exists merely as a mathematical quantity measuring the numerical order of material changes (and which can be defined as the proper time of the observer under consideration). Given two inertial frames, the transformations between the spatial coordinates of these two systems are given by equation (4), while the transformation of the rate of clocks, namely between the proper times of the observes of these two inertial systems, is given by equation (5).

Now, in the fundamental complex manifold $\mathbb{C}^4$ we define the concept of physical duration of motion as a proper, "true", physical scale for the proper time τ, namely for the numerical order, on the basis of equation:

$$t = \tau\left(1 - \frac{v^2}{c^2}\right) + \frac{vX}{c^2} \quad (6).$$

The physical time *t*, defined by equation (6) represents the duration of material motion as measured by the stationary observer O in the rest inertial frame. Equation (6) indicates that the numerical order may be considered as the internal structure of the physical, measurable time intended as duration.

By starting from the hypothesis that physical time is a scaling function of the fundamental numerical order of material change expressed by equation (6) and that the numerical order corresponding to the velocity of the moving observer with respect to the rest frame determines a re-scaling of the position of the object into consideration in the moving frame, one can show that the standard Lorentz transformations of Einstein's special relativity concerning the temporal coordinate and the first coordinate derive directly from a more fundamental arena equipped with the laws (4) and (5).

In summary, we can say that, in our approach, the duration of material changes satisfying the standard Lorentz transformation for the temporal coordinate is a proper, physical scaling function which emerges from the more fundamental numerical order and determines itself a re-scaling of the position measured by the moving observer expressed by the standard Lorentz transformation for the first spatial coordinate. Special Relativity equipped with formalisms (4) and (5) can also describe successfully all phenomena in 3D Euclidean space previously described by classical special relativity, such as aberration of light, Doppler effect, Jupiter's satellites occultation and radar ranging of the planets [3, 4, 7].

In [8] Sobczyk suggested an interpretation of special relativity in a complex vector-based language that is the natural generalization

of the Gibbs-Heaviside vector algebra of 3-dimensional space. Now here we want to extend Soboczyk's approach by considering mathematical formalisms (4) and (5) in the context of a complex 3-dimensional vector space $\mathbb{C}^3$. By following Soboczyk [8], we start by defining $\vec{b} = \{\vec{e}_1, \vec{e}_2, \vec{e}_3\}$ as an orthonormal basis of this complex space equipped with a complex scalar product defined as

$$A \circ B = \sum_{k=1}^{3} \alpha_k \beta_k = \alpha_1\beta_1 + \alpha_2\beta_2 + \alpha_3\beta_3 \quad (7)$$

for $A = \sum_{k=1}^{3} \alpha_k \vec{e}_k \in \mathbb{C}^3$ and $B = \sum_{k=1}^{3} \beta_k \vec{e}_k \in \mathbb{C}^3$ where $\alpha_k, \beta_k \in C$.

In the approach based on the complex space the event horizon of an

inertial system is a subset
$\mathcal{H} \subset \mathbb{C}^3$:

$$\mathcal{H} = \left\{\frac{X}{X} = \sum_{k=0}^{3} x_\mu \vec{e}_\mu \quad where \quad x_\mu \in \Re\right\} \quad (8)$$

and $x_\mu = x - v\tau$. Now, let $\mathcal{H}'$ be the event horizon of an inertial system moving along the x- axis with the velocity $v\vec{e}_1$ as seen by an observer in $\mathcal{H}$. Then the event horizons are related by the universal mapping

$$X' = Xexp(\phi e_1) \quad (9)$$

and the orthonormal rest frames by the boost $\vec{e}_k' = e^{-\frac{1}{2}\phi\vec{e}_1}\vec{e}_k e^{\frac{1}{2}\phi\vec{e}_1}$ for k=1,2,3 and the hyperbolic angle satisfies the following conditions

$$cosh\phi = \sqrt{1 - \frac{v^2}{c^2}} \quad (10)$$

$$senh\phi = \frac{v}{c}\sqrt{1 - \frac{v^2}{c^2}} \quad (11)$$

and thus
$\frac{v}{c} = tanh\phi$.
Suppose now that $\vec{X}(\tau) = \vec{X} - v\tau = x\vec{e}_1 + y\vec{e}_2 + z\vec{e}_3$ is the history of a particle moving in the inertial system $\mathcal{H}$ and that $\vec{X}'(\tau) = -v\tau + x'\vec{e}_1{}' + y'\vec{e}_2{}' + z'\vec{e}_3{}'$ is the history of the same particle in the inertial system $\mathcal{H}'$. The coordinates as measured in $\mathcal{H}$ are related to the corresponding coordinates as measured in $\mathcal{H}'$ by relations

$$e^{\frac{1}{2}\phi\vec{e}_1}X'e^{-\frac{1}{2}\phi\vec{e}_1} = e^{\frac{1}{2}\phi\vec{e}_1}Xe^{-\frac{1}{2}\phi\vec{e}_1} \quad (12).$$

This equation implies

$$-v\tau' + x'\vec{e}_1' = (-v\tau + x\vec{e}_1)(cosh\phi + \vec{e}_1 senh\phi) = cosh\phi(-v\tau + x\vec{e}_1)\left(1 + \vec{e}_1\frac{v}{c}\right) \quad (13)$$

and

$$y'\vec{e}_2' + z'\vec{e}_3{}' = y\vec{e}_2 + z\vec{e}_3 \quad (14)$$

which are the counterpart of the formalisms (8) and (9) in the complex space $\mathbb{C}^3$ and lead directly to Lorentz transformations. The physical consequence of these equations is therefore that the Minkowski space-time model $\mathbb{R}^4$ of special relativity is not fundamental but indeed is an emerging structure from a more fundamental complex space $\mathbb{C}^3$ where time exists merely as a mathematical quantity measuring the numerical order of material changes.

3. General Relativity in a Complex Space: mathematical formalism

Although General Relativity (GR) has got several experimental confirmations [9, 10], nevertheless it presents limits when strong gravitational fields are considered (which can lead to different interpretations of the sources of gravitational waves [11, 12]), as well as when one tries to search a compatibility with quantum theory.

In order to face some of the issues regarding general relativity, since the pioneering work of Jean-Emile Charon [13], several models have been developed by the theoretical physics community which are based on a complex space-time picture. For example, in order to treat the singularity at $r = 0$ of the Lorentzian Schwarzschild solution (which turns out to disappear on the real Riemannian section of the corresponding complexified space-time), in a series of papers [14-16] G. Esposito developed a version of complex general relativity where the Lorentzian space-time is replaced by a four-complex-dimensional complex-Riemannian manifold, with holomorphic connection and holomorphic curvature tensor. In this model, the Hamiltonian constraint is replaced by a geometric structure linear in the holomorphic multimomenta, and the mathematical formalism leads to some boundary conditions on two-complex-dimensional surfaces, which exhibit a link with the Penrose twistor programme.

More recently, in order to face the matter regarding the strong gravitational fields, Hess has proposed an algebraic extension of GR involving only real and pseudo-complex (called also hyper-complex) variables, which allows the investigation of the solutions for the limit of weak gravitational fields [17]. In Hess' pseudo-complex GR, the Einstein equations include an energy-momentum tensor, linked to vacuum fluctuations (dark energy), which assumes the form of an asymmetric ideal fluid [18]. In this approach, dark energy is chosen

in such a way that no event horizon appears and a general principle emerges, namely that mass not only curves the space (which leads to the standard GR) but also changes the vacuum properties in its vicinity, which in turn leads to an important deviation from the classical solution.

By following [19-22], in Hess' algebraic extension of GR one starts from a mapping of the real coordinates into the following pseudo-complex variables

$$X^\mu = x^\mu + I y^\mu \quad (15)$$

where $I^2 = \pm 1$, x^μ are the standard coordinates in space-time, y^μ is the complex component. Equation (15) implies that, when $I^2 = -1$ one obtains complex variables, when $I^2 = 1$ one has pseudo-complex variables. Hess' theory implies that, if one makes the variation of the action

$$S = \int dx^4 \sqrt{-g}\,(\Re + 2\alpha) \quad (16),$$

where $\Re$ is the Riemann scalar and the last term corresponds to the cosmological constant, α being constant in order not to violate the Lorentz symmetry, one obtains the Einstein equations of motion for each component

$$G^{\pm}_{\mu\nu} - \frac{1}{2} g^{\pm}_{\mu\nu} R^{\pm}_{\mu\nu} = 8\pi T^{\pm}_{\mu\nu} \quad \text{(where here } c = G = 1) \quad (17).$$

In each component the mathematical structure of the theory has the form of a theory of general relativity, where all principles and symmetries are satisfied. Equations (17) include the effects of a minimal length parameter l – which is not measurable in present observations – in the sense that it leads to a pseudo-complex length element squared given by relation

$$d\omega^2 = g_{\mu\nu}[dx^\mu dx^\nu + l^2 du^\mu du^\nu] \quad (18)$$

which preserves Lorentz symmetry. Equations (17) turn out to have the same structure as the standard general relativistic equations, except for the fact that the energy-momentum tensor appearing on the right hand side describes an an-isotropic ideal fluid. As a consequence of the appearance of this non-zero energy-momentum tensor, the mass not only curves space-time but also changes vacuum properties. The vacuum fluctuations are associated with the energy-momentum tensor $T_{\mu\nu}$ and turn out to increase with the strength of the gravitational field. Hence, since problems arise when the strength of the gravitational field is large, Hess' model predicts that the behaviour near the horizon is not physical and requires a modification.

Now, here our aim is to provide a generalization of the pseudo-complex GR developed by Hess by using the model of the

three-dimensional (3D) dynamic quantum vacuum (DQV) developed by two of the authors of this paper (DF and AS) in a series of recent works [23-29]. We will call our generalization of the pseudo-complex general relativity as "complex relativity in a three-dimensional (3D) dynamic quantum vacuum (DQV)".

In our model, GR emerges as the hydrodynamic limit of some underlying theory of a more fundamental microscopic 3D quantum vacuum condensate where each elementary particle is determined by elementary reduction-state (**RS**) processes of creation/annihilation of virtual pairs particles corresponding to opportune changes of a fundamental quantum vacuum energy density. In this model, the curvature of space-time characteristic of GR emerges as a mathematical value of a more fundamental energy density of quantum vacuum. The changes and fluctuations of the quantum vacuum energy density generate a curvature of space-time similar to the curvature produced by a "dark energy" density, through a quantized metric characterizing the underlying microscopic geometry of the 3D quantum vacuum [23-29].

In our model, in epistemological affinity with the results obtained by Santos [30-32], the quantized metric of the 3D quantum vacuum condensate is expressed by relation

$$d\hat{s}^2 = \hat{g}_{\mu\nu} dx^{\mu} dx^{\nu} \quad (19)$$

where here the (quantum operators) coefficients of the metric are defined (in polar coordinates) as

$$\hat{g}_{00} = -1 + \hat{h}_{00},\ \hat{g}_{11} = 1 + \hat{h}_{11},\ \hat{g}_{22} = r^2\left(1 + \hat{h}_{22}\right),\ \hat{g}_{33} = r^2 \sin^2\vartheta\left(1 + \hat{h}_{33}\right),$$
$$\hat{g}_{\mu\nu} = \hat{h}_{\mu\nu} \text{ for } \mu \neq \nu \quad (20).$$

As regards the coefficients (20), multiplication of every term times the unit operator is implicit and, at the order $O\left(r^2\right)$, in the light of equation (6) one obtains

$$\left\langle \hat{h}_{\mu\nu} \right\rangle = 0 \text{ except } \left\langle \hat{h}_{00} \right\rangle = \frac{8\pi G}{3}\left(\frac{\Delta\rho_{qvE}}{c^2} + \frac{35Gc^2}{2\pi\hbar^4 V}\left(\frac{V}{c^2}\Delta\rho_{qvE}^{DE}\right)^6\right) r^2 \text{ and}$$

$$\left\langle \hat{h}_{11} \right\rangle = \frac{8\pi G}{3}\left(-\frac{\Delta\rho_{qvE}}{2c^2} + \frac{35Gc^2}{2\pi\hbar^4 V}\left(\frac{V}{c^2}\Delta\rho_{qvE}^{DE}\right)^6\right) r^2 \quad (21).$$

where the metric (21) is close to Minkowski (namely, when the distance $r \to \infty$, one has $\hat{g}_{\mu\nu} \to \eta_{\mu\nu}$, where $\eta_{\mu\nu}$ is the Minkowski metric) and $\Delta\rho_{qvE}^{DE}$ are opportune fluctuations of the quantum

vacuum energy density which determine the dark energy density on the basis of relation

$$\rho_{DE} \cong \frac{35Gc^2}{2\pi\hbar^4 V}\left(\frac{V}{c^2}\Delta\rho_{qvE}^{DE}\right)^6 \quad (22)\ [23\text{-}29].$$

Here, therefore, dark energy emerges as energy itself of the 3D quantum vacuum. As a consequence of equation (22), in our approach of general relativity in a complex space, we propose that the fundamental arena is a pseudo-complex space $\mathbb{C}^4$ where the action (16) assumes the form

$$S = \int dx^4\sqrt{-g}\left(\Re + \frac{35Gc^2}{\pi\hbar^4 V}\left(\frac{V}{c^2}\Delta\rho_{qvE}^{DE}\right)^6\right) \quad (23).$$

Equation (23) represents the counterpart of the action (16) of Hess' model and its actual physical meaning at a more fundamental level. In other words, in our model, the action of the pseudo-complex space $\mathbb{C}^4$, which is the fundamental arena of general relativity, is directly associated with the fluctuations of the quantum vacuum energy density which mimic the action of dark energy.

By making the variations of the action (23) with respect to the metric $g_{\mu\nu}^{\pm}$, one obtains the following equations of motion

$$\Re_{\mu\nu}^{\pm} - \frac{1}{2}g_{\mu\nu}^{\pm}\Re_{\mu\nu}^{\pm} = 8\pi T_{\pm\,\mu\nu}^{\Lambda} \quad (24)$$

where

$$T_{\pm\,\mu\nu}^{\Lambda} = \lambda u_\mu u_\nu + \lambda\left(\dot{y}_\mu\dot{y}_\nu + u_\mu\dot{y}_\nu + u_\nu\dot{y}_\mu\right) + \frac{35Gc^2}{2\pi\hbar^4 V}\left(\frac{V}{c^2}\Delta\rho_{qvE}^{DE}\right)^6 g_{\mu\nu}^{\pm} \quad (25).$$

In the light of equations (24)-(25), the fluctuations of the quantum vacuum energy density characterizing the pseudo-complex space, lead to the existence of a minimal length parameter given by relation

$$\Delta x \geq \frac{\hbar}{2\Delta p} + \frac{\Delta p}{2\hbar}\left(2\pi^2/3\right)^{2/3} l^{2/3} l_P^{4/3} \quad (26)$$

(where l_P is Planck length),
which can be considered as the uncertainty in the measure of the position.
Since the minimal length (26) is difficult to measure, at a first order of approximation, one can neglect this parameter and project the above equations into their real part. In this way, one obtains

$$\Re_{\mu\nu} - \frac{1}{2}g_{\mu\nu}^{\pm}\Re = 8\pi T_{\mu\nu,\Re}^{\Lambda} \quad (27)$$

where $T_{\mu\nu,\Re}^{\Lambda}$ is real and is given by

$$T_{\mu\nu,\Re}^{\Lambda} = \left(\rho_{\mathrm{DE}} + p_\vartheta^\Lambda\right)u_\mu u_\nu + p_\vartheta^\Lambda g_{\mu\nu} + \left(p_r^\Lambda - p_\vartheta^\Lambda\right)k_\mu k_\nu \quad (28)$$

where ρ_{DE} is dark energy density (given by (22)), p_ϑ^Λ and p_r^Λ are the tangential and pressure respectively, u_μ are the components of the

four-velocity of the virtual particles of the medium and k^{μ} is a space-like vector in the radial direction, which satisfies relation $u_{\mu}k^{\mu} = 0$. Because of the presence of y_{μ} the following relations hold

$$\lambda = 8\pi\left(p_{\vartheta}^{\Lambda} + \rho_{\mathrm{DE}}\right), \quad \frac{35Gc^2}{\cancel{2\pi\hbar^4 V}}\left(\frac{V}{c^2}\Delta\rho_{qvE}^{DE}\right)^6 = 8\pi p_{\vartheta}^{\Lambda}, \quad \lambda y_{\mu}y_{\nu} = 8\pi\left(p_{r}^{\Lambda} - p_{\vartheta}^{\Lambda}\right)k_{\mu}k_{\nu} \quad (29).$$

Near the Schwarzschild radius the gravitational field is very strong and this condition corresponds to a singularity in the quantum vacuum energy density, which turns out to be proportional to the quantity $\frac{1}{\left(1-\frac{2V\Delta\rho_{qvE}}{c^2 r}\right)^2}$. As regards the fall-off of the negative energy density, which is finite at the Schwarzschild radius, in the light of the results obtained in [20], we can assume that it is a function of a parameter n and of the quantum vacuum energy density, i.e., proportional to $\frac{B_n}{r^n}$, where $B_n = b_n\left(\frac{V}{c^2}\Delta\rho_{qvE}\right)^n$ describes the coupling of the dark energy density (22) to the fluctuations of the quantum vacuum. In this way, the metric for the Kerr solution describing a rotating star is given by relations

$$g_{00} = -\frac{r^2 - 2\frac{V}{c^2}r\Delta\rho_{qvE} + a^2\cos^2\vartheta + \frac{b_n\left(\frac{V}{c^2}\Delta\rho_{qvE}\right)^n}{(n-1)(n-2)r^{n-2}}}{r^2 + a^2\cos^2\vartheta}$$

$$g_{11} = \frac{r^2 + a^2\cos^2\vartheta}{r^2 - 2\frac{V}{c^2}r\Delta\rho_{qvE} + a^2\cos^2\vartheta + \frac{b_n\left(\frac{V}{c^2}\Delta\rho_{qvE}\right)^n}{(n-1)(n-2)r^{n-2}}}$$

$$g_{22} = r^2 + a^2\cos^2\vartheta$$

$$g_{33} = (r^2 + a^2)sen^2\vartheta + \frac{a^2 sen^4\vartheta\left(2\frac{V}{c^2}r\Delta\rho_{qvE} - \frac{b_n\left(\frac{V}{c^2}\Delta\rho_{qvE}\right)^n}{(n-1)(n-2)r^{n-2}}\right)}{r^2 + a^2\cos^2\vartheta}$$

$$g_{03} = \frac{-2a\,sen^2\vartheta\frac{V}{c^2}r\Delta\rho_{qvE} + a\frac{b_n\left(\frac{V}{c^2}\Delta\rho_{qvE}\right)^n}{(n-1)(n-2)r^{n-2}}sen^2\vartheta}{r^2 + a^2\cos^2\vartheta} \quad (30)$$

where $0 \le a \le \frac{V}{c^2}\Delta\rho_{qvE}$ is the counterpart, in our model, of the mass parameter of the Kerr solution and n=3,4,... The Schwarzschild solution is obtained for $a = 0$. Equations (30) become the standard Kerr solution of GR when $B_n = 0$.

For n=4 and $B_n = \frac{81}{8}$ one finds that an event horizon for $a = 0$ occurs at $\frac{3}{2}\frac{V}{c^2}\Delta\rho_{qvE}$. The event horizon is eliminated by imposing that the parameter B_n, in a given volume V of space, has a lower limit given by relation

$$B_n = \frac{2(n-1)(n-2)}{n}\left[\frac{2(n-1)}{n}\right]^{n-1}\left(\frac{V}{c^2}\Delta\rho_{qvE}\right)^n \quad (31).$$

As a consequence, an event horizon occurs at the coordinates

$$r_h = \frac{2(n-1)}{n}\frac{V}{c^2}\Delta\rho_{qvE} \quad (32)$$

which, for example, acquires the value $r_h = \frac{4}{3}\frac{V}{c^2}\Delta\rho_{qvE}$ for n=3, $r_h = \frac{3}{2}\frac{V}{c^2}\Delta\rho_{qvE}$ for n=4. In this situation, a mass function can be defined given by relation

$$m(r) = \left[1 - \frac{27}{32}\frac{V^3}{r^3c^6}\Delta\rho_{qvE}^3\right] \quad (33).$$

For the Schwarzschild regime the g_{00} component assumes the form $g_{00} = 1 - \frac{2\left[1-\frac{27}{32r^3c^6}\frac{V^3}{}\Delta\rho_{qvE}^3\right]}{r}$, which reduces to the well-known expression in GR when the term proportional to $\frac{1}{r^3}$ in the mass (33) vanishes.

4. Predictions of the model of general relativity in complex space

Let us explore now the predictions of our model of "complex relativity in a 3D DQV", in particular as regards the motion of a material object in a circular orbit and the perihelion shift of Mercury.

As the regards the motion of a particle in a circular orbit, our model implies that the orbital frequency is given by

$$\omega_n = \frac{1}{a+\sqrt{\frac{2r}{h_n(r)}}} \quad (34)$$

where

$$h_n(r) = \frac{2}{r^2} - \frac{n\left(\frac{V}{c^2}\Delta\rho_{qvE}\right)^n}{(n-1)(n-2)r^{n+1}} \quad (35).$$

When B_n reaches its lower limit given by the right-hand side of equation (31), the quantity $h_n(r)$ assumes the form

$$h_3(r) = \frac{2}{r^4}\left(r^2 - \frac{16}{9}\right), \quad h_4(r) = \frac{2}{r^5}\left(r^3 - \frac{27}{8}\right) \quad (36).$$

In light of equations (36), one finds that, in our model of complex extension of general relativity, the orbital frequency of a material object in a circular orbit is always lower than the corresponding frequency predicted by GR, and that some differences only appear

near the Schwarzschild radius, and thus in situations which are near the size of a black hole, in agreement with the results obtained by Hess in [19-21]. Here, however, we can provide a deeper justification of this crucial result, namely in terms of the energy density fluctuations of the 3D DQV. In other words, in our approach of general relativity in a complex space, we can say that the orbital frequency of a material object in a circular orbit is always lower than the corresponding frequency predicted by GR and that some differences only appear near the Schwarzschild radius, as a consequence of more fundamental fluctuations of the energy density of the 3D DQV.

Moreover, in our approach, the orbital frequency fixes for B_n a maximum at

$$r_{\omega_{max}} = \left[\frac{n(n+2)b_{max}}{6(n-1)(n-2)}\right]^{\frac{1}{n-1}} \frac{V}{c^2}\Delta\rho_{qvE} \quad (37)$$

which is independent of the value of a. Equation (37) implies that for $n = 3$ the value is approximately $r = 1.72\frac{V}{c^2}\Delta\rho_{qvE}$ and for $n = 4$ it is $r = 1.89\frac{V}{c^2}\Delta\rho_{qvE}$ and therefore that the zero of the orbital frequency and the position of its maximum tend to grow with increasing n.

In analogy to the results obtained by Hess [20], one of the main predictions of our model is that the accretion disc emission will show both an outer dark ring and an inner bright ring. However, unlike Hess' model, here we can provide a deeper explanation of the formation of these outer dark ring and inner dark ring of the accretion disc emission, in terms of the fundamental fluctuations of the quantum vacuum energy density.

At the maximum of the orbital frequency – corresponding to opportune energy density fluctuations of the 3D DQV – neighbouring orbitals have nearly the same orbital frequency, circular orbits emerge and thus less friction and less heating are present. As a consequence of this, a dark ring appears in the accretion disc emission near the position $r_{\omega_{max}}$, which is 1.72 for $n = 3$. On the other hand, above and especially below the position of the maximum, the change in orbital frequency is large, the disc gets heated and, consequently, the gradient becomes significantly stronger and a bright ring takes place. The position of the maximum, which gives the position of the dark ring, is approximately the same for $n = 3$ and $n = 4$. For $b_n \to 0$, the curve is similar to the one for GR. Our model predicts a deviation for larger a with respect to the results of GR. At about $a = 0{,}45\frac{V}{c^2}\Delta\rho_{qvE}$ all orbits in our model are stable up to the

surface of the star, which turns out to lie at approximately $\frac{4}{3}\frac{V}{c^2}\Delta\rho_{qvE}$. For $a = \frac{V}{c^2}\Delta\rho_{qvE}$, in GR the last stable orbit is at $r = \frac{V}{c^2}\Delta\rho_{qvE}$. For lower values of $a = 0{,}45\frac{V}{c^2}\Delta\rho_{qvE}$ the particles reach further inside and due to the decrease of the potential, more energy is released, producing a brighter disc.

In our model, the reason for the dark ring and bright ring of the accretion disc emission lies in the variability of the dragging effect caused by the energy density fluctuations of the 3D DQV. A possibility to experimentally distinguish standard general relativity and our model of general relativity in a complex space is thus represented by the observation of the differences in the structure of an accretion disc determined by the quantum vacuum energy density fluctuations.

On the other hand, a further prediction of our model is that the surface of the horizon of events is given by

$$r_h = \frac{2(n-1)}{n}\frac{V}{c^2}\Delta\rho_{qvE} \quad (38).$$

This parameter can be put in correlation with gravitational wave analysis (see, for example, [33]) and with observations of the Event Horizon Telescope [34]. Our model predicts thus that, in the Schwarzschild case (a = 0), the size of the black hole is smaller than in the standard theory while, in the Kerr case with $a = 1\frac{V}{c^2}\Delta\rho_{qvE}$, it turns out to be larger.

Let us analyse now the predictions of our model of general relativity in a complex space as regards the perihelion shift of Mercury, the first and most famous experimental test of general relativity. In this regard, our aim is to show that GR gives the dominant contribution, while the additional ones from its complex extension are too low to be measured (a result that is compatible with the fact that the gravitational field in the solar system is simply too weak, and in agreement with the results obtained by Hess in [19-21]).

In our model, one starts from the following real length element in the Schwarzschild solution, depending of the quantum vacuum energy density fluctuations

$$ds^2 = -\left(1 - \frac{2\left[1-\frac{27}{32r^3}\frac{V^3}{c^6}\Delta\rho_{qvE}^3\right]}{r}\right)dt^2 + \left(1 - \frac{2\left[1-\frac{27}{32r^3}\frac{V^3}{c^6}\Delta\rho_{qvE}^3\right]}{r}\right)^{-1} dr^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2) \quad (39).$$

If one divides (39) by ds^2 and uses the definition $L = -1$ for the Lagrangian suggested in [28], one obtains

$$1=\left(1-\frac{2\left[1-\frac{27}{32}\frac{V^3}{r^3c^6}\Delta\rho_{qvE}^3\right]}{r}\right)\dot{t}^2-\left(1-\frac{2\left[1-\frac{27}{32}\frac{V^3}{r^3c^6}\Delta\rho_{qvE}^3\right]}{r}\right)^{-1}\dot{r}^2-r^2\left(\dot{\theta}^2+sin^2\theta\dot{\varphi}^2\right)\quad(40)$$

where the dot refers to the derivative in s. By imposing the angular momentum conservation $r^2\dot{\varphi}=const$, that the motion takes place in the plane $\theta=\frac{\pi}{2}$ and that $\left(1-\frac{2\left[1-\frac{27}{32}\frac{V^3}{r^3c^6}\Delta\rho_{qvE}^3\right]}{r}\right)\dot{t}=h=const$, equation (40) yields

$$1=-\left(1-\frac{2\left[1-\frac{27}{32}\frac{V^3}{r^3c^6}\Delta\rho_{qvE}^3\right]}{r}\right)^{-1}h^2-\left(1-\frac{2\left[1-\frac{27}{32}\frac{V^3}{r^3c^6}\Delta\rho_{qvE}^3\right]}{r}\right)^{-1}\dot{r}^2-\frac{\Delta x^2}{r^2}\quad(41),$$

where Δx is given by (28).

Now, if one changes the derivative with respect to s to the one with respect to φ (which we denote with r') and then multiplying (41) by $\left(1-\frac{2\left[1-\frac{27}{32}\frac{V^3}{r^3c^6}\Delta\rho_{qvE}^3\right]}{r}\right)$, after some mathematical manipulations, the following relation is obtained

$$\left(1-\frac{2\left[1-\frac{27}{32}\frac{V^3}{r^3c^6}\Delta\rho_{qvE}^3\right]}{r}\right)=h^2-\frac{\Delta x^2}{r^4}(r')^2-\frac{\Delta x^2}{r^2}\left(1-\frac{2\left[1-\frac{27}{32}\frac{V^3}{r^3c^6}\Delta\rho_{qvE}^3\right]}{r}\right)\quad(42).$$

Then, by defining the variable $u=\frac{1}{r}$, after some mathematical manipulations, one arrives at equation

$$u''+u=\frac{V\Delta\rho_{qvE}}{c^2\Delta x^2}+3\frac{V\Delta\rho_{qvE}}{c^2}u^2-\frac{27}{8}\frac{V^4\Delta\rho_{qvE}^4}{c^8\Delta x^2}u^3-\frac{81}{16}\frac{V^4\Delta\rho_{qvE}^4}{c^8\Delta x^2}u^5\quad(43).$$

Now, in the 3D quantum vacuum of the complex space, the **RS** processes corresponding to elementary fluctuations of the quantum vacuum energy density determine a motion of virtual particles endowed with frequencies

$$\omega=\frac{2\Delta\rho_{qvE}V}{\hbar n}\quad(44)$$

and thus give rise to a total velocity of the quantum vacuum

$$v_{qv}=\frac{2\Delta\rho_{qvE}V}{\hbar n}R\quad(45)$$

namely

$$v_{qv}=\frac{2Ac^2\Delta x^2}{\hbar n}R\quad(46)$$

in each given volume into consideration, where R is the distance from the centre of that volume and the quantity

$$A = \frac{V\Delta\rho_{qvE}}{c^2\Delta x^2} \quad (47)$$

can be defined as the areal velocity on the planetary plane. As a consequence, in light of the dependence between velocity of the quantum vacuum and areal velocity on the planetary plane

$$A = \frac{\hbar n v_{qv}}{2c^2\Delta x^2 R} \quad (48)$$

equation (43) may be conveniently expressed as

$$u'' + u = A + \frac{2c^2\Delta x^2 R\varepsilon}{\hbar n v_{qv}} u^2 - \frac{A}{8}\left(\frac{2c^2\Delta x^2 R\varepsilon}{\hbar n v_{qv}}\right)^3 u^3 - \frac{1}{16}\left(\frac{2c^2\Delta x^2 R\varepsilon}{\hbar n v_{qv}}\right)^4 u^5 \quad (49)$$

where the number $\varepsilon = 3\frac{V^2\Delta\rho_{qvE}^2}{c^4}\frac{1}{\Delta x^2}$ is very small in case of the solar system, namely of the order 10^{-7}. In equation (49), the first term on the right hand side corresponds to the classical, Newtonian contribution, while the second term reproduces the standard relativistic correction which leads to the known perihelion shift of Mercury in function of the velocity of the quantum vacuum. The next terms are explicit new contributions – always associated with the velocity of the 3D DQV – which arise from the complex space of GR and, since ε is of the order of 10^{-7} in the solar system, these deviations can be hardly detected in solar system observations, where therefore the standard view of GR and our interpretation of GR in complex space can be considered indistinguishable from each other.

5. Conclusions and perspectives

In this paper a new interpretation of special relativity and general relativity in a complex space has been proposed. The model developed in this paper suggests that the fundamental arena of special relativity is a complex $\mathbb{C}^4$ space which is time-invariant in the sense that time is not its dimension but exists merely as a mathematical quantity measuring the numerical order of material changes (and which can be defined as the proper time of the observer under consideration) and the physical duration of motion can be defined as the "true" physical scale for the numerical order. Here, the Minkowski space-time model is indeed an emerging structure from the more fundamental complex space $\mathbb{C}^3$.

As regards general relativity, in our model the fundamental arena is a pseudo-complex space $\mathbb{C}^4$ where the action is directly associated with the elementary energy density fluctuations of the 3D quantum vacuum which occur in correspondence to RS processes of

creation/annihilation of virtual particles. The model of "complex relativity in a 3D space" here introduced predicts that, as a consequence of the behaviour of the fluctuations of the quantum vacuum energy density, the orbital frequency of a material object in a circular orbit is always lower than the corresponding frequency predicted by general relativity, and that some differences only appear near the Schwarzschild radius. Moreover, as regards the perihelion shift of Mercury, it is completely coherent with the results of general relativity and provides a justification of these results in terms of a fundamental velocity of the quantum vacuum.

On the other hand, Gödel's development of general relativity shows that Einstein field equations lead to the contradiction, namely, one could move back in time and kill his grandfather and so he could not be born. He understood that his development of General Relativity proves that time has no physical existence and nobody can travel in time. Still today he is misunderstood by thinking that his work is proving that time travel is possible [35]. The idea that the fundamental arena of general relativity is a complex space throws new perspectives of solution to this paradox of time travel: nobody can travel in time because universal space is time-invariant.

Finally, it must be emphasized that there are several issues that have to be addressed in this model, in particular as regards cosmology. In this regards, the perspective is opened that the Friedmann equation, which combine the GR field equations and the Friedmann-Lemaitre-Robertson-Walker (FRLW) metric describing a homogeneous, isotropic universe, with matter and energy uniformly distributed as a perfect fluid, can be expressed in the form

$$H^2(a) = \frac{8\pi G}{3}\left(V\Delta\rho_{qvE}a^{-3} + \rho_{rad}a^{-4} + \frac{35Gc^2}{\pi\hbar^4 V}\left(\frac{V}{c^2}\Delta\rho_{qvE}^{DE}\right)^6 e^{-3\int_a^1[1+\omega(a')]d\ln a'}\right) - \frac{kc}{a^2} \quad (50)$$

where $\Delta\rho_{qvE}$ are the fluctuations of the quantum vacuum energy density corresponding to the appearance of matter, ρ_{rad} is the density of the quantum vacuum associated with radiation, which satisfies relation

$$E_{rad} = \rho_{rad}c^2 \quad (51),$$

a is the dimensionless scale factor describing the evolution of the universe, $\omega = \frac{p}{\Delta\rho_{qvE}c^2}$, p is the pressure, H is the Hubble parameter, and k is a parameter which for $k = 0$ corresponds to a flat universe. Equation (50) implies that, as a consequence of the behaviour of the quantum vacuum energy density, the early universe was radiation-

dominated, until the temperature dropped enough for matter density to being to dominate. The energy density of dark energy is constant if its equation of state parameter $\omega = 1$. Because the matter energy density drops as the scale factor increased, the fluctuations of the quantum vacuum $\Delta\rho_{qvE}^{DE}$ associated with the action of dark energy began to dominate in the recent past and, at the present time ($a(t) = 1$), we live in a universe dominated by these type of fluctuations of the vacuum [36]. As regards the consequences of the modified Friedmann equation (50) regarding the behaviour of the scale factor of the universe, further research will give you more information.

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THE WORLD MEDIUM AS THE PRIMORDIAL MATTER. GENESIS OF MASS-TIME-CHARGE QUANTITIES

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Abstract

The work is a development of the concept outlined in monograph "Mathematical foundations of ether mechanics". The hypothesis is introduced that at the deepest level of matter there are no mass-time-charge properties; these properties are synthesized with the complication of forms of motion. Mechanical models for the synthesis of these properties and a mathematical description of the models are presented. On the basis of these models, the fundamentals of physics, alternative to the physics of the XX century, are presented: an alternative mathematical explanation of the Michelson experiment and an analytical derivation of the de Broglie formula are given. Mechanical models of electromagnetism are presented. In conclusion, it is concluded that the physics of the XX century are palliative methods of description, but not the actual structure of the Universe

Keywords: World medium; Ether; Mass; Time; Charge; Electron; De Broglie formula: Electromagnetism

1 Introduction

The totality of theoretical arguments indicates that the world medium (let's call it ether) must exist. However, the experiment does not confirm this philosophical and qualitative reasoning. The ether has not been detected by direct experiment, although there are many indirect experiments in favor of its existence.

The problem of ether is the greatest problem of physical science. If we believe that the greatest scientific problem can be solved in an ordinary way by finding some equations, without cardinal changes in the approach to considering the movement of this medium, then this means underestimating the greatness of the problem. To describe the ether, it is necessary to move to another level of thinking. It is necessary to define the most general approaches to the study of ether, that is, to create a PHILOSOPHY of ETHER. Being dismissive of philosophy, one can wander for hundreds of years unsuccessfully in attempts to construct the theory of ether within the framework of secondary, non-fundamental concepts.

To create the philosophy of the ether, consider the hierarchy of forms of motion of matter. According to the doctrine of the forms of motion of matter, there are forms of motion that differ in degree of complexity. The lowest form is the mechanical form of motion (described in terms of Newton's physics), the highest forms are biological, social and other forms. The higher forms are formed from the lower ones through synthesis – a jump-like transition from a lower form to a higher one. With such a leap, new properties, attributes of matter arise. To describe a higher form requires more terms and concepts than to describe a lower form. Following this logic, it can be assumed that the "primordial matter" should not have any properties at all: all properties arise in the process of complicating the forms of movement. One of the expressions of this thesis is Kelvin's maxim: "...it is scarcely possible to help anticipating in idea the arrival at a complete theory of matter, in which all its properties will be seen to be attributes of motion" [1]. Within the framework of this logic, we come to the conclusion that the description of the microcosm should be simpler than the description of the macrocosm. Such a thesis is in contradiction with modern physics, in which, for example, it is stated that "the quantum mechanical description is more complicated than the classical one". From the standpoint of this concept, experiments that are not understood by the science of the XX century can be explained in the framework of incomparably simpler, and at the same time model mechanical representations.

Let us introduce the hypothesis that the lowest form of motion of matter, the "primordial matter" is ether. And also assume that the resting ether has no properties at all inherent in the objects studied by Newton's physics. The ether has no "mass density", there is no fundamental quantity "time", there is no property "electric charge"; all these properties must be explained by the mechanical motion of the

ether. Ether is not an ordinary macroscopic liquid or gas, which is described on the basis of generally accepted theories of continuous media. Instead of complicating the properties of the ether, which was carried out when trying to describe the ether, there is a simplification, a transition to a lower form of motion of matter. The motion of the ether can be described using only three mechanical quantities: energy E, momentum $\bar{Q}$, and extension l.

In the monograph [2] these philosophical arguments are put on a concrete mathematical basis. The interpretation of the experimental facts is presented from the standpoint of the kinetic theory of matter, according to which all conceivable space is filled with some homogeneous medium (medium, ether, physical vacuum) and vortices can exist in this medium. The verbal formula of the kinetic theory of matter is written as follows:

SUBSTANCE (AND FIELD) = MATTER (ETHER) + MOTION (I)

According to (I), a medium at rest has no properties (including mass). If mechanical motion is introduced into the medium, then a substance or field appears. All properties of matter are attributes of mechanical motion.

According to the concept of Cartesianism, all natural phenomena must have a mechanical model. This means that all physical quantities must be expressed as functions of only mechanical quantities. The mechanical quantities describing motion are energy E, momentum $\bar{Q}$, and extension l. Thus, instead of the basic system l, m, t of quantities of Newton's physics, a system $l, E, \mathbf{Q}$ of quantities is proposed.

2 The Ether model

Let there be a continuous superfluid medium consisting of infinitesimally small particles-points, which, like a photon, have no rest mass. Unlike photons, ether points can be at rest. If such a medium is at rest, then the energy density and, accordingly, the mass density are zero. If the points of the ether are moving, then they have energy and mass. The dependence of the energy E of the unit volume of the medium on the magnitude of the pulse Q is the same as for a photon:

$$E = cQ \tag{1}$$

In the usual interpretation, this formula means that the photon energy E is equal to the product of the photon velocity c by the magnitude of the pulse Q. In the proposed basic system of quantities, there is no concept of time, so there is no concept of the speed of light. The value c is not the speed of light, but the proportionality coefficient in a linear relationship (1). The value c is measured not in

meters per second, but in units of fundamental quantities $[E/Q]$. The equation of motion of the ether [2-3]

$$-\bar{\bar{\nabla}}p = \bar{\bar{\nabla}}a^2 \tag{2}$$

The acting vector in equation (2) is a vector **a**. The modulus of the vector **a** is equal to the geometric mean of the modules of the vectors **c** and **q**

$$q/a = a/c \text{ , or } a^2 = cq = \varepsilon, \tag{3}$$

where **q** is the momentum density, ε is the energy density. For comparison, we write down the Euler equation of an ideal medium (let us call it "Eulerian fluid") in the absence of external volumetric forces [5]:

$$-\frac{1}{\rho_E}\nabla p = \frac{d\mathbf{v}}{dt} = \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}\nabla)\mathbf{v} \text{ (Euler)} \tag{4}$$

Comparison of equations (2) and (4) shows, firstly, that the equation of the world medium of this model is simpler than the equation of macroscopic media. Secondly, there is no partial derivative in equation (2) with respect to time. However, the equation is also valid for non–stationary modes, since the arguments of motion - energy and momentum are implicitly present in the right side of the equation.

3 The genesis of the quantities "mass" and "time"

Consider the genesis of mass. The vectors **c** and **q** coincide in the direction, so we can introduce a scalar function $\rho(\varepsilon)$ that establishes the proportionality between the vectors **c** and **q**:

$$\mathbf{q} = \rho(\varepsilon)\cdot\mathbf{c} \tag{5}$$

The ratio (3) will be written as follows:

$$\varepsilon = \mathbf{cq} = cq = a^2 = \rho c^2 \tag{6}$$

The following relations follow from relations (3) and (6):

$$\mathbf{c} = \mathbf{a}/\sqrt{\rho}\,; \tag{7}$$

$$\mathbf{q} = \mathbf{a}\cdot\sqrt{\rho}\,. \tag{8}$$

The value $\rho(\varepsilon)$ in (5) and (6) can be considered as a variable mass density of a moving medium. If the medium is at rest, then the energy density ε and mass density $\rho(\varepsilon)$ are zero. If energy is introduced into the medium, then mass density also arises. Passing in (6) from differential quantities to integral ones, we obtain Einstein's formula

$$E = mc^2 \tag{9}$$

Thus, we obtain the value "mass" not as an argument of motion, but as a function of mechanical quantities $l, E, \mathbf{Q}$. The dimension of this function is: $[m]=[Q^2/E]$.

The genesis of time is the most difficult part of the theory to understand. According to the proposed concept, there is no fundamental value of "time". It is antiphysical to believe that there is some kind of "time" that "flows" even when there are no changes in space. Changes in quantities in space do not occur due to the presence of the fundamental quantity "time", but due to the transfer of portions, quanta of field change. Thus, these changes must be described not as function of mystical quantity "time", but as function of real mechanical quantities $l, E, \mathbf{Q}$. That is, the process of "time flow" is a mechanical process and can be mathematically described using mechanical quantities. The partial derivative in time $\partial/\partial t$ disappears from the equations of motion.

According to Newton's representation, the total derivative d/dt of some quantity in time is equal to the sum of the partial derivative $\partial/\partial t$ in time and the convective derivative $(\mathbf{v}\nabla)$

$$d/dt = \partial/\partial t + (\mathbf{v}\bar{\nabla})$$

The convective derivative is a real value. But the partial derivative is an expression of Newton's mystical idea of time as a global quantity that flows independently of the state of motion. In the theory presented, the process of the "flow of time" is material and represents the convection of quantities characterizing the field. If there is an object that creates a field at a point A, then when the parameters of the object change, these changes come to the point A with some delay Δt

$$\Delta t = 2l/c \tag{10}$$

The more fundamental quantity in this definition is the quantity c. The time interval Δt is a secondary value. The "time" function can be entered as the sum of these elementary delay values

$$t = \sum_{i=1}^{N} \Delta t_i \ , \tag{11}$$

where N is the number of changes emission acts. The synthetic quantity t in (11) is a function of "time", measured in units of primary quantities; $[t]=[l \cdot Q/E]$. Formula (11) shows that time "flows" only when changes occur. Therefore, the "time" function is an integral, cumulative function of changes.

Since there is no value of "time", the concept of the velocity V of a body as a derivative of the distance in time also does not exist. The concept of translational velocity $\mathbf{V}$ of a body can be introduced, similar to the Hamiltonian formulation of dynamics as a derivative of the motion's energy T in momentum Q:

$$V = \partial T / \partial Q \tag{12}$$

3 The Michelson's Experiment

On the basis of such a model of the ether, there is a multiple simplification of physical representations. Consider, for example, the explanation of Michelson's negative result. The presented theory translates the solution of this problem from the category of esoteric problems of four-dimensional pseudo-Euclidean space-time into the category of problems for high school students. It is only necessary to move on to another system of concepts.

The principle of the constancy of the speed of light, introduced by Einstein, leads in SRT to monstrous distortions of physical representations. According to G. Minkovsky, space as an independent category disappears, and a new category arises – a four-dimensional pseudo-Euclidean space-time. In this concept, the explanation of the constancy of the "speed of light" does not require violence to physical representations. The speed of a quantum of light relative to a moving inertial reference frame (IRF) in any IRF is always equal to c, since the value c is the proportionality coefficient in linear dependence (1). Consequently, deformations of solid rods do not occur and the formulas of SRT kinematics are erroneous.

However, a difficulty arises. There are formulas for the dynamics of SRT

$$E_0 = m_0 c^2 \tag{13}$$

$$E^2 - c^2 Q^2 = m_0^2 c^4 \tag{14}$$

Where E is the total energy of a moving particle; $\mathbf{Q}$ is the momentum of a moving particle; c is the speed of light; m_0 is rest mass of the particle; E_0 - rest energy. These formulas have been experimentally tested many times, so there is no doubt about their validity, In SRT these formulas are obtained using kinematics formulas. Thus, the position arises that the Lorentz formulas are incorrect, but the SRT dynamics formulas are correct, In order to overcome this contradiction, it is necessary to prove the dynamics formulas without the help of kinematics formulas. Formula (13) is a special case of the proven formula (9), so only the relation (14) requires proof.

3.1 Proof of SRT dynamics formulae without kinematics formulae

Let's write down the expression of the total momentum $\mathbf{Q}$ of the particle

$$\mathbf{Q} = m\mathbf{V} \tag{15}$$

Where m is the total mass of the particle; $\mathbf{V}$ is the velocity of the particle. The vectors $\mathbf{V}$ and $\mathbf{Q}$ coincide in the direction, so it is possible to work in scalar form:

$$Q = mV \tag{16}$$

According to (9), the value of the total energy E of the particle divided by c^2 should be used as the total mass

$$m = E / c^2 = m_0 + T / c^2$$

The velocity V, according to the definition (12), is a derivative of the kinetic energy T by momentum:

$$V = \frac{\partial T}{\partial Q} = \frac{\partial (T + E_0)}{\partial Q} = \frac{\partial E}{\partial Q}, \tag{17}$$

Formula (16) takes the form:

$$Q = \frac{E}{c^2} V = \frac{E}{c^2} \frac{\partial E}{\partial Q} \tag{18}$$

The relation (18) is a differential equation with separable variables E and Q:

$$\frac{1}{c^2} E \cdot dE = Q \cdot dQ \tag{19}$$

We integrate both parts of the equation

$$\frac{1}{c^2} \int E \cdot dE = \int Q \cdot dQ$$

General solution of the equation

$$\frac{1}{c^2} E^2 = Q^2 + C, \tag{20}$$

where C is an unknown constant. We determine the constant C from the initial conditions. If $Q = 0$, then $E = E_0 = m_0 c^2$. Hence $C = E_0^2 / c^2$. Substitute in (20)

$$\frac{1}{c^2} E^2 = Q^2 + \frac{E_0^2}{c^2},$$

or

$$E^2 = c^2 Q^2 + E_0^2 = \left| E_0^2 = m_0^2 c^4 \right| = c^2 Q^2 + m_0^2 c^4$$

$$E^2 = c^2 Q^2 + m_0^2 c^4$$

This is the formula (14), but it was obtained without the use of SRT kinematics. Thus, based on this model of the world medium, experimentally confirmed SRT formulas for dynamic quantities – energy and momentum – have been obtained. Lorentz formulas lose their theoretical basis (they did not have an experimental basis) and "go into oblivion."

The above proof changes the priorities of physics. The formulas of SRT dynamics are correct, but the space is three-dimensional and Euclidean, which greatly simplifies the theoretical consideration of physical problems. In addition, the ether is returning to science, the existence of which has been a "religion" for most

scientists for centuries. However, physics of the first quarter of the XX century, having abandoned the ether, also abandoned mechanical, visual models of phenomena. As a result, a complex of sciences called "quantum physics" appeared. The presented concept shows that a rational explanation of experiments for which quantum mechanics has not found model explanations is possible precisely from the standpoint of the existence of the ether, that is, the world medium of the given model,

4 Circulation of surface forces

In the XIX century, when the concept of ether was the dominant doctrine of theoretical physics, properties of the intermediate medium were experimentally discovered, for which no theoretical explanations were found. The main of these experimentally discovered properties are the following two groups of experiments:

Problem 1) Transversity of electromagnetic waves;

Problem 2) the impossibility of detecting a world medium (ether) by a direct experiment, for example, such as the Michelson experiment.

The inability of theoretical physics to explain these experiments led to the fact that by the end of the XIX century the models of the intermediate medium became so cumbersome and artificial that no one believed in such esoteric models. Therefore, at the beginning of the XX century, with the creation of the SRT, there was a rejection of the concept of ether. The stated concept asserts that the reason for the impossibility of constructing a satisfactory model of the medium is that physics tried to create a model of the ether within the framework of Newton's physics, based on the theory of macroscopic continuous media. In [2-4], two errors of the theory of the ideal medium were revealed, on the basis of which the physics of the XIX century tried to construct a model of the ether. Solutions to these problems are presented:

Solution of problem 1): existence of circulation of surface forces along the contour of the vortex ring.

Solution to problem 2): erroneous idea of the value of "time": "time" is not a fundamental quantity, but a function of more fundamental quantities.

The solution of the second problem was described in section 3. Another problem of the ether's theory of the XIX century (historically arose earlier) is the problem of the transversity of light waves. If we consider light to be waves in the ether, then experiments on the polarization of light prove the transversity of these waves. However, this conclusion contradicts the ideas of science about the ideal medium. There is a Lagrange theorem, according to which the propagation of vortex motions through an ideal medium is impossible. The transversity of light waves means that a rotor or circulation of surface forces (or other related quantities: speed, acceleration)

must be present in the equation of the medium. Great forces of science of the XIX century were directed to solve this paradox, but the problem was never solved.

This problem is solved by the Author; the solution is set out below. The movements of the ether are potential, there is no circulation of velocity or acceleration along a closed circuit; therefore, the search for science of the XIX century in this direction is erroneous. The essence of the solution is that there is a circulation of surface forces along the contour of the vortex ring. At the same time, circulation exists only in the integral form, the ultimate transition to the differential form is impossible. Light and other electromagnetic vibrations are waves in the world medium; however, the transversity of these waves is a consequence of the existence not of a rotor of surface forces, but of the existence of a circulation of surface forces along a finite contour.

In the ideal medium described by equation (2), various types of flows are possible. Since movement is potential, there is potential Φ of a vector $\mathbf{a}_0$.

$$\nabla\Phi = \mathbf{a}_0 \tag{21}$$

The meaning of the subscript 0 for the vector $\mathbf{a}_0$ will be explained further. All possible flows must be a combination of the simplest flows of an ideal medium. The simplest flows are the drain and the source, but these flows are physically impossible, since they assume the appearance of matter "out of nothing" at the source points and the disappearance of matter at the drain points. The simplest, physically possible flow is a vortex ring in the ether.

To prove the existence of the circulation of surface forces, we first consider the motion of an ideal liquid described by the Euler equation (4). According to the dynamics of ideal media, the vortex ring field is described by Ampere's theorem [5, p. 290]:

$$\Pi_A = -\frac{\Gamma}{4\pi}\int_{\Sigma}\frac{\partial}{\partial n}\left(\frac{1}{r}\right)d\sigma, \quad \text{(Ampere)} \tag{22}$$

The velocity $\mathbf{v}$ of the liquid particles is equal to the potential Π_A gradient:

$$\mathbf{v} = -\frac{\Gamma}{4\pi}\nabla\int_{\Sigma}\frac{\partial}{\partial n}\left(\frac{1}{r}\right)d\sigma \tag{23}$$

According to (22), the Ampere potential Π_A created by the vortex ring is equivalent to the potential created by the continuous distribution of dipoles over the surface tightened by the contour of the vortex ring. This theorem was obtained by Ampere under the assumption that the motion of the liquid is strictly potential, that is, there is no rotor or circulation of surface forces. However, there is a circulation of surface forces along the contour of the vortex ring. This circulation exists in a

somewhat unusual form, not described in the world literature on continuum dynamics. The motions of a continuous liquid are potential if there is an isotropy of stresses. In an ideal liquid, the tangential stresses are zero, the stress tensor is spherical. So, by all visible signs, a rotor and, accordingly, the circulation of surface forces cannot exist in an ideal liquid.

However, when vortex filaments exist in an ideal liquid, there is a phenomenon of the so-called ***integral anisotropy*** (the term was introduced by me - A.V.). This phenomenon was first noted by Maxwell [6, p. 115], but he did not obtain the corresponding mathematical consequences from this phenomenon. It consists in the fact that normal stresses are isotropic, but the forces of normal stresses are different, that is, there is anisotropy of the forces of normal stresses. As a result, the circulation along any infinitesimal contour is zero, but the circulation along the contour of the vortex ring is not zero; at the same time, the ultimate transition to an infinitesimal contour is impossible. On the basis of this idea, the existence of the circulation of surface forces is proved, but not in the form in which physics of the XIX century tried to find circulation.

To prove this statement, consider the stationary motion of a vortex ring in an ideal liquid described by the Euler equation (4). In [2] it is shown that the translational velocity of the ring is equal to the sum of two components: 1) gradient velocity $\mathbf{V}_{GRAD}$ and 2) circulation velocity $\mathbf{V}_{CIRC}$:

$$\mathbf{V}_{SUM} = \mathbf{V}_{GRAD} + \mathbf{V}_{CIRC} \tag{24}$$

The component $\mathbf{V}_{GRAD}$ exists both in the vortex pair and in the vortex ring, but the component $\mathbf{V}_{CIRC}$ is caused by the curvature of the vortex line and exists in the vortex ring only. Let's analyze this component.

In stationary motion, there is an equality of forces acting on the ring element dl: the centripetal force $d\mathbf{F}_{CP}$ directed to the center of the ring and the centrifugal force $d\mathbf{F}_{CF}$ acting from the center. The origin of the force $d\mathbf{F}_{CP}$ is illustrated in Fig. 1. Two tensile forces $\mathbf{G}_1$ and $\mathbf{G}_2$ of equal magnitude and directed along the normal to the cross-section plane act on the ends of the element dl. The magnitude G of these forces can be calculated as follows [2, p. 146]:

$$G \approx \lim_{\sigma\to\infty} \int_{\sigma} (p_0 - p)\cdot d\sigma, \tag{25}$$

where σ is the cross-section of the vortex; p_0 is the pressure at infinity; p is pressure in the cross section of the vortex. Since the element dl is curved, and the forces $\mathbf{G}_1$ and $\mathbf{G}_2$ are directed at an angle to each other, then there is a resultant

$d\mathbf{F}_{CP}$ of these forces directed to the center of the ring. The magnitude of this centripetal force

$$dF_{CP} = G \cdot d\alpha \;, \tag{26}$$

where $d\alpha$ is the central angle of the element dl.

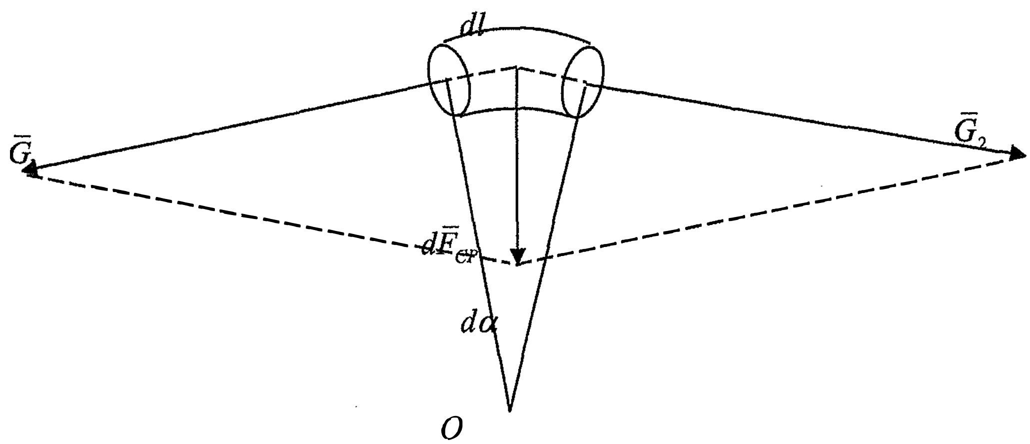

Fig. 1: Origin of the force $d\mathbf{F}_{CP}$ directed to the center of the ring. Two tensile forces $\mathbf{G}_1$ and $\mathbf{G}_2$ act on the ends of the element dl. Since the element is curved, there is a resultant of these forces directed to the center of the ring.

Since the element dl moves with translational velocity $\mathbf{V}_{CIRC}$, the Zhukovsky lifting force $d\mathbf{F}_{Zh} \equiv d\mathbf{F}_{CF}$ acts on it:

$$dF_{CF} = \rho_E \cdot \Gamma \cdot V_{CIRC} \cdot R_R \cdot d\alpha \tag{27}$$

where Γ is the circulation; ρ_E is density of the Eulerian fluid; R_R is the radius of the ring. Equating (26) and (27), we get

$$V_{CIRC} = \frac{G}{\rho_E \cdot \Gamma \cdot R_R} \tag{28}$$

Multiply the numerator and denominator of the right side (28) by the circumference of the ring $2\pi R_R$. The numerator in this case can be represented as the circulation of the surface force $\mathbf{G}$ along the contour L of the ring. The ratio takes the following form:

$$V_{CIRC} = \frac{1}{2\pi R_R^2 \rho_E \cdot \Gamma} \oint_L \mathbf{G} \cdot d\mathbf{l} \tag{29}$$

Thus, part $\mathbf{V}_{CIRC}$ of the translational velocity of the vortex ring can be expressed as a function of the circulation of the surface force. As is known, the potentiality of surface forces underlies the hydrodynamics of ideal media, therefore, the proof of the existence of the circulation of surface forces makes great changes in the theory. The author has investigated two main consequences of this proof:

1) The appearance of an addition to Ampere's theorem (23). This additive explains the genesis of the "electric charge of an electron" value, that is, the possibility of constructing mechanical models of electromagnetism. Since there is a circulation of surface forces, Ampere's theorem will be valid not in a stationary coordinate system, but in a system moving at speed $\mathbf{V}_{CIRC}$. To switch to a fixed coordinate system, it is necessary to add velocity $\mathbf{V}_{CIRC}$ to the velocity field (23). We obtain the corrected Ampere theorem [2, p. 127]:

$$\mathbf{v}_{SUM} = -\frac{\Gamma}{4\pi} \nabla \int_{\Sigma} \frac{\partial}{\partial n} \left(\frac{1}{r} \right) d\sigma + \mathbf{V}_{CIRC} \,. \tag{30}$$

2) The possibility of explaining the transversity of electromagnetic disturbances propagating in the medium. The solution to this problem is presented in the following.

Thus, the presented theory solves the problems of physics of the XIX century, due to the impossibility of solving them (within the framework of Newton's ideas), the concept of ether was abandoned. However, in the XX century, after the creation of SRT, physics took a different path. Esoteric ideas of SRT have changed the mentality and worldview of physics: science has abandoned visual mechanical models. Emerging problems began to be solved only mathematically, without visual explanations. The following presentation shows how, on the basis of the proposed model of the world medium, the problems that led to the emergence of a complex of sciences under the general name "quantum physics" are explained.

5 Electron structure

The presented concept asserts that all phenomena, without exception, are based on a mechanical model. The theory asserts that such abstract concepts of modern physics as "electron charge e", "wave function ψ" can be understood visually, as properties of the mechanical movements of the ether. More specifically, these properties are the parameters of an electron as a vortex ring in the ether, that is, attributes of the motion of the world medium.

We introduce the hypothesis that an electron is a vortex ring in the ether. Thus, according to the presented concept, the electron is the simplest, physically possible solution of the Laplace equation for ether, with an addition due to the existence of circulation of surface forces. Based on such an electron structure, an explanation of the nature of the "electric charge" of an electron as a mechanical property of a vortex ring is given, mechanical models of electromagnetism are constructed, and rational explanations are given to experiments of the first quarter of the XX century. In the following presentation it is shown that:

1) "Charge" is an invariant of the motion of the vortex ring in the ether;

2) The de Broglie equation for the wave function is the equation of stationary motion of a vortex ring in the ether;

3) The electron spin is the intrinsic angular momentum of the vortex ring, which occurs when the ring is introduced into a constant magnetic field;

4) The wave properties of the electron can also be explained from these positions. A vortex ring is an elastic system. When this system is perturbed, vibrations occur in it, propagating along the perimeter of the ring.

It was shown above how simple both physically and mathematically, on the basis of the proposed concept the problems are solved, which are explained by modern science on the basis of SRT. Similarly, on the basis of the proposed concept, the picture of phenomena falling within the competence of quantum mechanics is multiply simplified. At the same time, the proposed theory constructs mechanical, visual models of phenomena. Experiments that do not have a model explanation in quantum mechanics find rational explanations from the standpoint of the stated theory of the ether.

In the science of the XIX century, there were many hypotheses about the nature of the electrical and magnetic properties of matter as mechanical properties of a vortex ring. Among these works, we can mention the works of Maxwell [6], Helmholtz [7], Kelvin [8] and etc. However, all these works assumed the solution of the problem within the framework of Newton's physics. In addition to this, the SRT, which appeared at the beginning of the XX century, extremely complicated the system of the Universe. Therefore, physics has found nothing better than the rejection of visual models and the formalization of mathematical description.

Let's consider how the presented concept explains the genesis of the electromagnetic properties of matter. The results obtained in section 4 for the ideal fluid of the Eulerian model can be transferred to a vortex ring in the ether. We consider only a thin vortex ring for which $V_{CIRC} \gg V_{GRAD}$. Ampere's theorem

$$\nabla\Phi_A = \mathbf{a}_A = -\frac{C}{4\pi}\nabla\int_{\Sigma}\frac{\partial}{\partial n}\left(\frac{1}{r}\right)d\sigma \tag{31}$$

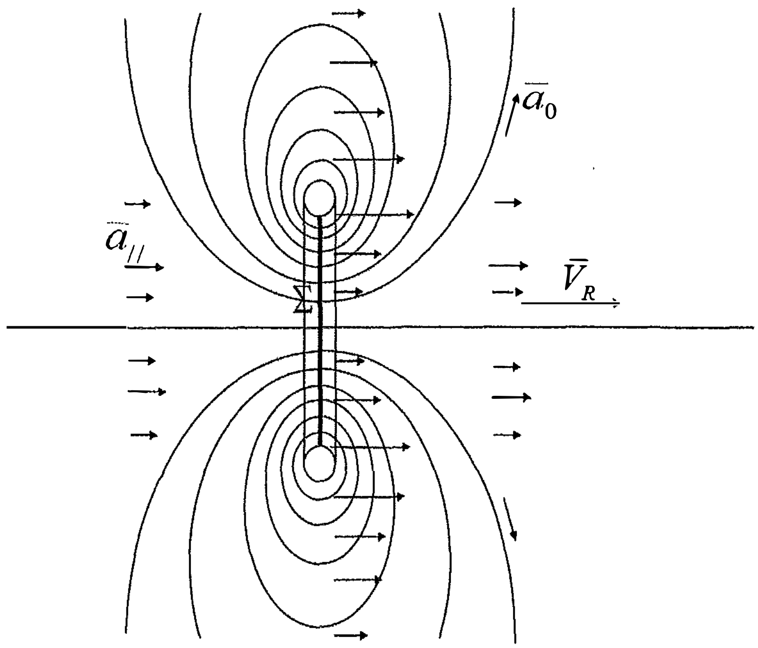

Fig. 2: Image of the field of a freely moving thin vortex ring in the ether. The field consists of two components: 1. Vector $\mathbf{a}_0$ lines - solutions of the Laplace equation for the dipole; 2. An additional vector $\mathbf{a}_{//}$ characterizing the kinetic energy density of the translational motion of the vortex ring.

Due to the existence of circulation of surface forces, an addition to Ampere's theorem arises. This additive can exist in two forms: 1) for the free movement of the ring; 2) for a ring stopped by external barrier. For the first mode, the corrected Ampere theorem [2, p. 161]:

$$\mathbf{a}_{R1} = -\frac{C}{4\pi}\nabla\int_{\Sigma}\frac{\partial}{\partial n}\left(\frac{1}{r}\right)d\sigma + \sqrt{\frac{\rho}{2}}\cdot\mathbf{V}_R, \tag{32}$$

where Φ_A is the Ampere potential, C is the circulation of the vector $\mathbf{a}_0$ around the axis of the vortex; Σ is the surface resting on the contour of the vortex ring. The image of this field is shown in fig. 2. The field consists of two components: 1)

Vector $\mathbf{a}_0$ lines, this term expresses Ampere's theorem; 2) Lines of an additional vector $\mathbf{a}_{//} = \sqrt{\rho_0 / 2} \cdot \mathbf{V}_R$

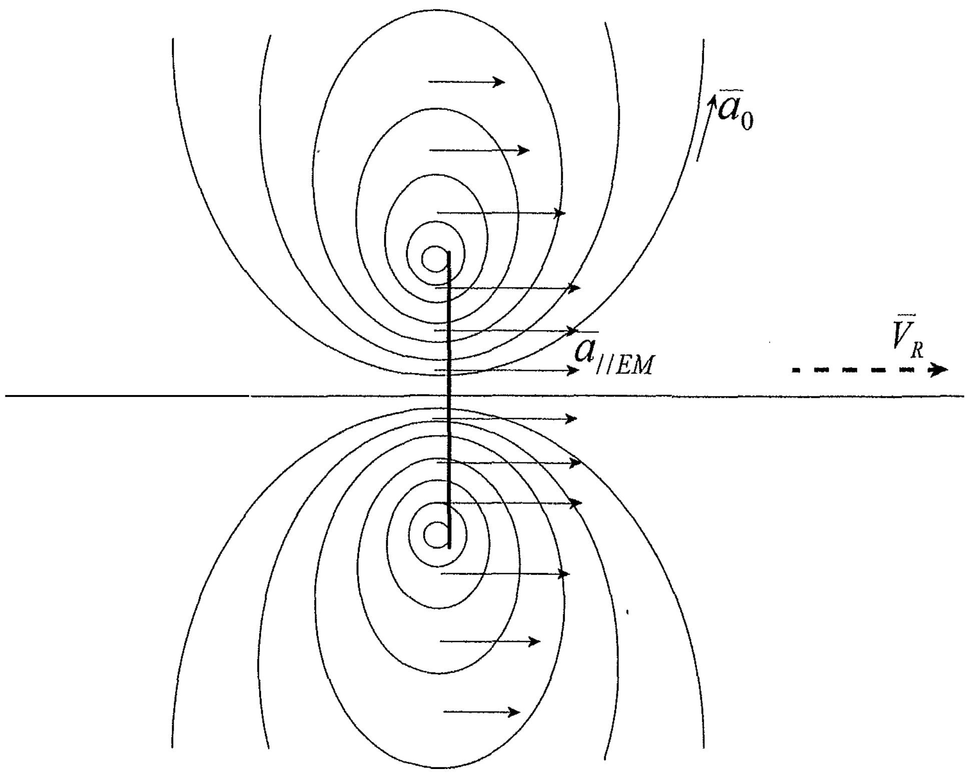

Fig. 3: Image of the field of a thin vortex ring stopped by external forces, that is, with an additive in the form (34). The barrier holding the ring from free translational motion is depicted by a bold line adjacent to the vortex core. Since the translational velocity is zero, the vector $\mathbf{V}_R$ is represented by a dotted line. The field consists of two components: 1. Vector $\mathbf{a}_0$ lines – solutions of the Laplace equation for the dipole; 2. Vector $\mathbf{a}_{//EM}$ – the vector of the satellite flow that occurs when the vortex ring is decelerated

If the ring is stopped by external forces, that is, an obstacle is imposed on the translational speed of the ring (Fig. 3), and then the following process occurs. Since when the ring stops, the translational energy $\varepsilon_{//} = \rho V_R^2 / 2$ of the thin ring cannot

disappear, it is transformed into the energy of the translational flow of ether. This flow moves in the direction of the stopped translational velocity of the ring at a speed of c.

Thus, when the ring stops, the ring becomes a "micro pump", driving a rectilinear vector $\mathbf{a}_{//EM}$ flow through itself. Let's call this stream an accompanying or satellite stream (sputny potok). The total field consists of the sum of the Ampere field (31) and the satellite flow field:

$$\mathbf{a}_{R2} = \mathbf{a}_A + \mathbf{a}_{//EM}, \tag{33}$$

Or in expanded form:

$$\mathbf{a}_{R2} = -\frac{C}{4\pi}\nabla\int\limits_{\Sigma}\frac{\partial}{\partial n}\left(\frac{1}{r}\right)d\sigma + \mathbf{a}_{//EM}, \tag{34}$$

where $\mathbf{a}_{//EM}$ is the vector of the satellite stream.

Let's make the following statement. ***The total intensity of the vector $\mathbf{a}_{//EM}$ flow is a quantity that appears in modern physics under the name "electron charge e".***

$$e = \int\limits_{\Sigma}\mathbf{a}_{//EM}\cdot\mathbf{n}\cdot d\sigma, \tag{35}$$

where Σ is an infinite cross-sectional plane. The dimension of the flow power coincides with the dimension of the charge in the natural system of units

$$[a\cdot\sigma] = M^{1/2}L^{3/2}T^{-1} = [e] \tag{36}$$

The meaning of this statement and the corresponding mechanical models will be presented in the following presentation. The subscript $_{EM}$, as will become clear from the following presentation, means that vector $\mathbf{a}_{//EM}$ describes the electromagnetic field. Depending on the different physical conditions in which the vortex ring can be placed, the satellite flow can create either a magnetic field or an electric field.

Consequently, the total field of an electron as a vortex ring in the ether consists of two components: 1) a vector $\mathbf{a}_0$, that is, the field of the ring itself, and 2) an additive $\mathbf{a}_{//}$ is a vector that can exist in two forms. It is shown in [2] that the additive $\mathbf{a}_{//}$ creates the properties of an electron, which are designated by the term "electromagnetism", and the vector $\mathbf{a}_0$ field creates a complex of phenomena that fall within the competence of quantum mechanics.

Thus, the original, innate properties of matter "mass", "time", "charge", which are considered fundamental quantities in modern physics, do not exist. These properties are synthesized when mechanical motion is introduced into the resting

ether. It is shown that these quantities can be expressed as functions of mechanical quantities $l, E, \mathbf{Q}$.

6 The physical meaning of the de Broglie equation

The basis of quantum mechanics is the de Broglie relation. At low energies, this formula has the form [9, p. 443]:

$$\frac{\lambda}{2\pi} = \frac{\hbar}{mV} \text{ (de Broglie, 1923)} \tag{37}$$

where λ is the de Broglie wavelength, $\hbar$ is the reduced Planck constant, m is the mass of the particle, V is the translational velocity of the particle. Formula (37) was obtained by de Broglie heuristic method, without analytical proofs. A visual mechanical model of this phenomenon does not exist in modern physics, so the number of interpretations of the (37) is permanently growing and is currently approaching twenty; this indicates that none of the interpretations is satisfactory. As a result, all quantum physics is just a set of mathematical methods of calculations, without understanding the physical essence of the phenomena described.

The theory being presented constructs simple, mechanical models of these phenomena. According to the proposed theory, ***the de Broglie equation is the equation of stationary motion of a vortex ring in the world medium.***

Let us first consider the logical prerequisites for the emergence of this idea, which subsequently led to a rigorous mathematical proof of the hypothesis. Another consequence follows from the elementary proof made in section 4. Consider formula (28) for the stationary motion of a vortex ring in an ideal fluid of the Eulerian model. Let's write this formula in the following form:

$$R_R = \frac{G}{\rho_E \cdot \Gamma \cdot V_{CIRC}}.$$

This formula is similar in structure to the de Broglie formula (37): in both formulas, the values either coincide or are close in meaning. The formula (28) was obtained by the Author in 1985, and there were expectations that if the equation of the world medium (ether) is obtained, then the equation of stationary motion of the vortex ring in the ether will take the form of the de Broglie equation (37). These expectations were justified: in 2005, on the basis of the already obtained ether equation (2), the equation of stationary motion of the vortex ring in the ether of the presented model was analytically obtained

$$R_R = \frac{K}{m \cdot V_R}, \tag{38}$$

where m is mass-energy of the ring; R_R is radius of the ring; V_R is translational velocity of the ring; K is angular momentum of the medium rotating around the circular axis of the vortex. If we assume that the magnitude of this moment is equal to the reduced Planck constant $\hbar$:

$$K \equiv \hbar, \tag{39}$$

and the circumference $2\pi R_R$ of the ring is the de Broglie wavelength λ:

$$2\pi R_R \equiv \lambda, \tag{40}$$

then we get the de Broglie formula. Formula (38) takes the following form:

$$R_R = \frac{\hbar}{m \cdot V_R}. \tag{41}$$

Relation (41) is the equation of stationary motion of a vortex ring in the world medium; we will call it the ***electron equation***. Based on (41), rational explanations of the formulas of quantum mechanics are given. The science of the first quarter of the XX century, having found this ratio heuristically, "blindly", could not understand its real mechanical meaning. Therefore, in order to interpret the experiments, a deformation of physical representations was carried out, remaining within the framework of Newton's ideas about the qualitative difference between matter and vacuum.

6.1 Proof of the relation (38)

Let us find out what form, in the case of a vortex ring in the world medium of the presented model, the relation (28) takes, which is valid for a thin ring in an Eulerian fluid. We consider the problem with simplifying assumptions, with the sole purpose of identifying the main pattern.

Consider the stationary motion of a thin vortex ring in the ether. The ring element dl is affected by the same forces that were considered in Section 4 when analyzing a vortex ring in an Eulerian fluid (Fig. 1). In stationary motion, there is an equality of the "centripetal" force $d\mathbf{F}_{CP}$ acting in the direction of the center of the ring and the "centrifugal" force $d\mathbf{F}_{CF}$ acting from the center.

Consider centripetal forces. Relation (24) shows that, in general, the translational velocity of the ring consists of two components: the gradient component $\mathbf{V}_{GRAD}$ and the component $\mathbf{V}_{CIRC}$ caused by the curvature of the vortex thread. According to some estimates, which we do not give here, for a thin vortex ring in the ether, the force due to the curvature of the vortex thread exceeds the gradient component of the force by several orders of magnitude. Therefore, the component $\mathbf{V}_{GRAD}$ is small

compared to $\mathbf{V}_{CIRC}$. Therefore, we believe that the entire translational velocity of the ring is due to the circulation of surface forces.

We consider the problem in the coordinate system associated with the vortex ring (Fig. 4). We introduce a Cartesian coordinate system xOy: the direction of the axis x coincides with the direction of the translational velocity vector $\mathbf{V}_R$ of the ring, the axis y lies in the plane of the ring. We also introduce a polar system r,φ where the angle φ is measured from the axis x.

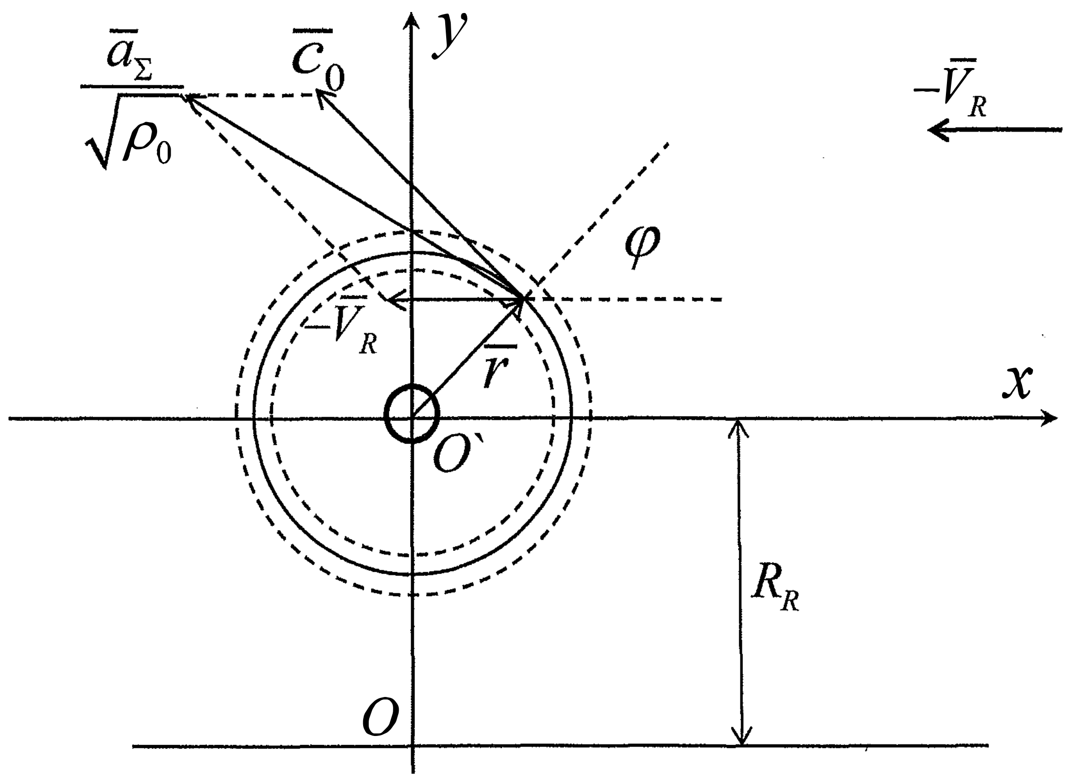

Fig. 4: The cross section of the vortex ring by the plane in which the translational velocity vector of the ring lies, in a moving coordinate system; O is the center of the ring, $O`$ is the center of the vortex, R_R is the radius of the ring. Dotted circles represent a circular vortex element with a thickness dr inside which the investigated vector $\mathbf{a}_0$ current line is located

Just as in an Eulerian fluid, the formula (25) is valid for the value G. The relation for the magnitude of the "centripetal" force dF_{CP} acting on the element dl of the vortex ring has the same form (26) as in the Eulerian fluid.

Consider the cross section of a vortex ring. To simplify the analysis, let the current lines in the vortex be concentric circles. Consider the circular element $r, r+dr$ of the vortex cross-section. The contribution dG to the magnitude of the force G given by this element is equal to:

$$dG = (p_0 - p) \cdot 2\pi r \cdot dr = 2\pi \cdot q \cdot c \cdot r \cdot dr,$$

since

$$p_0 - p = \varepsilon = cq$$

The contribution $\delta(dF_{CP})$ of the circular element to the "centripetal" force dF_{CP} created by the element dl is equal to:

$$\delta(dF_{CP}) = dG \cdot d\alpha = \frac{2\pi qcr \cdot dr \cdot dl}{R_R} \tag{42}$$

Let's analyze the centrifugal force $d\mathbf{F}_{CF}$ acting on the element dl. We will make preliminary remarks. This problem is similar to the well-known hydrodynamic problem of the motion of a cylinder with circulation in an ideal medium of the Eulerian model [10, p. 175], however, there are significant differences. Firstly, the medium under consideration has the property of superfluidity; in this case, the medium flows through each other. As a result of such mutual flow, the interaction energy arises [2, p. 117]. Secondly, simplifying assumptions were made, as a result of which it was possible to solve the problem without introducing the method of complex variables.

Consider a current line in a circular element $r, r+dr$. Let's determine the total vector $\mathbf{a}_\Sigma$ formed when the ether runs into a vortex moving relative to the ether. The modulus of the vector $\mathbf{a}_0$ on the considered current line before summation with the incoming flow is equal to:

$$a_0 = C / 2\pi r. \tag{43}$$

The total vector $\mathbf{a}_\Sigma$ can be defined as follows. Let's define the velocity vector $\mathbf{c}_0$ in the vortex. The modulus of this vector $\mathbf{a}_0$ according to (8) is equal to:

$$c_0 = a_0 / \sqrt{\rho_0},$$

and the vector $\mathbf{a}_0$ direction coincides with the direction of the vector $\mathbf{a}_0$. Then we geometrically sum the vector $\mathbf{c}_0$ with the velocity vector of the incoming flow $-\mathbf{V}_R$. We get a vector $\mathbf{a}_\Sigma / \sqrt{\rho_0}$ whose square is:

$$\frac{a_\Sigma^2}{\rho_0} = c_0^2 + V_R^2 + 2c_0V_R\cos(\mathbf{c}_0, -\mathbf{V}_R),$$

where $(\mathbf{c}_0, -\mathbf{V}_R)$ is the angle between the vectors $\mathbf{c}_0$ and $-\mathbf{V}_R$.

The square of the module of the total vector $\mathbf{a}_\Sigma$ is equal to:

$$a_\Sigma^2 = \rho_0(c_0^2 + V_R^2 + 2c_0V_R \cdot \sin\varphi) = \rho_\Sigma \cdot c^2, \tag{44}$$

where

$$\rho_\Sigma = \rho_0\left(1 + \frac{V_R^2}{c^2} + \frac{2V_R\sin\varphi}{c}\right);$$

where φ is the angle between the axis x and the radius vector $\mathbf{r}$ drawn from the center of the vortex $O`$ to the point M at which the vectors $\mathbf{c}_0$ and $-\mathbf{V}_R$ are summed:

$$\varphi = \frac{\pi}{2} - (\mathbf{c}_0, -\mathbf{V}_R);$$

When the incoming flow passes through the vortex, the angle $(\mathbf{c}_0, -\mathbf{V}_R)$ is smaller $\pi/2$ on the upper half of the vortex, so the pressure on the upper half of the vortex decreases. On the lower half of the vortex, on the contrary, the angle $(\mathbf{c}_0, -\mathbf{V}_R)$ is greater $\pi/2$, so the pressure increases here. At the same time, due to the symmetry of the pressure distribution pattern relative to the axis y, the sum of the projections of forces acting along the axis x is zero. There is a centrifugal force $d\mathbf{F}_{CF}$ (analogous to the Zhukovsky force in an Eulerian fluid) directed from the origin $O`$ in the direction of increasing values y. The force $d\mathbf{F}_{CF}$ acting on the element dl of the ring is calculated using equation (2), where the square of the modulus of the vector $\mathbf{a}_\Sigma$ is determined by the ratio (44). Projecting the resulting ratio onto the axis y, we get:

$$-\frac{\partial p}{\partial y} = \frac{\partial}{\partial y}\left[\rho_0(c^2 + V_R^2 + 2cV_R\sin\varphi)\right] = 2\rho_0 \cdot cV_R\frac{\partial}{\partial y}\left(\frac{y}{r}\right).$$

The derivative on the right side is equal to:

$$\frac{\partial}{\partial y}\left(\frac{y}{r}\right) = \frac{(\partial y/\partial y)\cdot r - y\cdot\partial r/\partial y}{r^2} = \left|\frac{\partial r}{\partial y} = \frac{2y}{2\sqrt{x^2+y^2}} = \frac{y}{r}\right| =$$

$$= \frac{r - y^2/r}{r^2} = \frac{r^2 - y^2}{r^3} = \frac{x^2}{r^3} = \frac{\cos^2\varphi}{r}$$

Substituting this derivative into the previous expression, we get:

$$-\frac{\partial p}{\partial y}=2\rho_0\cdot cV_R\frac{\partial}{\partial y}\left(\frac{y}{r}\right)=\frac{2\rho_0\cdot cV_R\cos^2\varphi}{r} \tag{45}$$

To calculate the contribution created by a circular element of thickness $r, r+dr$ and length dl, multiply (45) by the volume element $d\tau = r\cdot dr\cdot dl\cdot d\varphi$ and integrate along the angle φ from the angle $\varphi=0$ to 2π. We get:

$$dF_{CF}=2\rho_0\cdot cV_R dr\cdot dl\int_0^{2\pi}\cos^2\varphi\cdot d\varphi=2\pi\rho_0\cdot cV_R dr\cdot dl. \tag{46}$$

Ratios (42) and (46) are formulas for centripetal and centrifugal forces acting on an elementary layer $r, r+dr$, length dl. In stationary motion, the centripetal and centrifugal forces acting on the layer are equal. Therefore, we equate ratios (42) and (46):

$$\frac{2\pi qcr\cdot dr\cdot dl}{R_R}=2\pi\rho\cdot cV_R dr\cdot dl. \tag{47}$$

Now we need to integrate (47) along the radius r from radius r_0 to infinity, where r_0 is the radius of the cavitation cavity in the center of the vortex. Before integrating (47) by radius r, we multiply both parts of the equality by the radius. Since the density ρ depends on the radius, we write the density without the index "zero". Having reduced by an amount c, we write the integration in the following form:

$$\frac{dl}{R_R}\int_{r0}^{\infty} qr\cdot 2\pi r\cdot dr=V_R dl\int_{r0}^{\infty}\rho\cdot 2\pi r\cdot dr \tag{48}$$

Strictly, the upper limit of integration should be not ∞, but the radius R_R of the ring, however, for an infinitely thin ring, these integration limits are equivalent. When integrating (48), the integral in the left part is equal to the moment of momentum dK of the medium rotating around the element dl of the vortex filament:

$$\frac{dK}{dl}=\int_0^{\infty} qr\cdot 2\pi r\cdot dr,$$

and the integral in the right part is equal to the mass per unit length of the vortex filament:

$$\frac{dm}{dl}=\int_0^{\infty}\rho\cdot 2\pi r\cdot dr.$$

Integrating over the entire circumference of the ring, we get:

$$\frac{K}{R_R} = V_R \cdot m,$$

or

$$R_R = \frac{K}{m \cdot V_R},$$

This is the formula (38). In this formula K is the sum of the moments of momentum of elementary disks impaled on a circular axis:

$$K = R_R \int_0^{2\pi} d\alpha \int_0^{\infty} qr \cdot 2\pi r \cdot dr, \qquad (49)$$

m is the mass-energy of the medium involved in the vortex motion:

$$m = \frac{1}{c^2} \int_\tau \varepsilon \cdot d\tau$$

Thus, the formula (38) is proved. The very fact of the complete coincidence of the structures of formula (38) and de Broglie formula (37) indicates a lot: this coincidence can hardly be accidental. However, in order for the stated interpretation of the de Broglie formula to become a theory, all the quantities considered in this proof must be calculated. In [2], the calculation and evaluation of these values were performed.

It is necessary to comment on the above sequence of determining the total vector $\mathbf{a}_\Sigma$. When obtaining the ratio (44), the procedure of geometric summation of vector $\mathbf{c}_0$ and the vector $-\mathbf{V}_R$ of the incoming flow velocity was used, as a result of which the vector $\mathbf{c}_\Sigma = \mathbf{a}_\Sigma / \sqrt{\rho_0}$ modulus may be greater than the speed of light (in the sense of the concept of "speed of light" given in section 2. However, this does not mean that superluminal "speeds" are possible. To sum up the movements, it is necessary to geometrically sum up not the velocity vectors, but the vectors $\mathbf{a}_i$ of the flows superimposed on each other. In [2], a vector $\mathbf{a}_i$ addition scheme is shown, as a result of which the result does not differ from (44).

The formula (38) is proved only at low, non-relativistic energies of the translational motion of the ring. Therefore, it is necessary to further expand, interpolate this ratio to a range of higher energies, like the de Broglie ratio, which is extended to the entire range of electron energies.

Another direction of further work is the analysis of the properties of a vortex ring for non–stationary ring modes, which is an extension of the de Broglie equation from a stationary mode to a non-stationary one. In quantum mechanics, the Schrodinger equation is used for this.

7 Further development of the kinetic theory of matter

On the basis of the presented model of the ether and the genesis of the quantities mass, time, charge, a further, increasingly complex structure of the Universe can be understood and constructed. Firstly, those concepts of Newtonian physics for which there cannot be any visual models in Newtonian physics can be rationally understood. First of all, this applies to the concept of potential energy, as well as the related concept of interaction force.

According to the kinetic theory of matter, elementary particles are vortices in the world medium – ether. The vector $\mathbf{a}$ field of each vortex extends theoretically to infinity. The fields of particles overlap each other, while the vector $\mathbf{a}$ summation of vectors occurs and the interaction energy E_{IA} is formed

$$E_{IA} = \int_{\tau} a_1 a_2 \cdot \cos\alpha \cdot d\tau \qquad (50)$$

Where $\mathbf{a}_1$, $\mathbf{a}_2$ are the motion vectors of vortices 1 and 2, τ is the volume of interaction. The force $\mathbf{F}_{12}$ of interaction between vortices arises, as a result of which atoms are formed; atoms combine into molecules and macroscopic bodies are formed. Each macro body consists of many interconnected vortices, so there is a field around the bodies formed as a result of the superposition of fields of many particles. This total field is the gravitational field of bodies.

In the monograph [2] the genesis of other concepts of Newton's physics are shown. Thus, Newton's physics describes a higher form of motion of matter relative to the ether.

8 Consequences of the formula (41)

To explain experimental facts that have no visual models in quantum mechanics, twentieth-century physics offers interpretations that cannot be called explanations; they should be called "justifications based on postulates." In quantum mechanics, particles have a set of esoteric properties; these properties are simply attributed to particles based on the thesis "this is the nature of things." This impossibility of a simple explanation of the phenomena of transformation of matter into a field and back is inherent in all theories that contrast matter and vacuum. The construction of a simple mechanism of such transformation is possible only on the basis of the theory of continuous media, that is, the kinetic theory of matter. According to the proposed concept, the essence of phenomena is very simple, but experimental manifestations of this essence can be quite complex.

The analytical proof of the formula obtained by de Broglie heuristic method changes the approach to these experimentally obtained properties; all properties

receive a visual mechanical explanation. Let's consider brief summaries of these explanations.

8.1 Uncertainty of the electron position

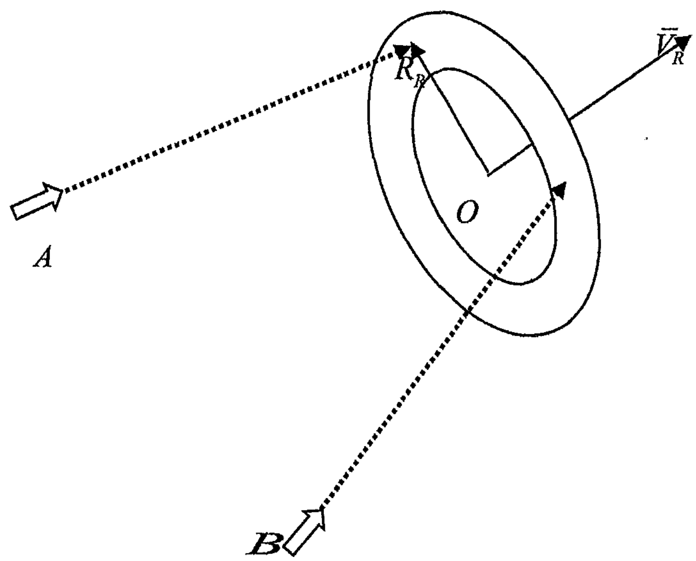

Fig. 5: Explanation of the physical meaning of Heisenberg's "uncertainty principle". The collision of probing projectiles A and B with an electron - vortex ring does not occur at the same point, but at any of the points of the circumference of the ring, at a distance R_R from the center of the ring, that is, from the point O at which (according to the concepts of the substantial theory) the electron is located.

Consider the uncertainty of the electron's position, which has entered science under the name of the "Heisenberg uncertainty principle". The electron is not a point object, but a vortex ring (Fig. 5). The collision of the ring with other micro–objects does not occur at the same point, but at any of the points of the circumference of the ring, since only in the center of the vortex there is a cavitation cavity impervious to probing projectiles. Therefore, when an electron collides with different objects, different electron coordinates are obtained. For a quantitative explanation, we write (41) in the following form:

$$R_R \cdot mV_R = \hbar .$$

This equality sets the lower bound of the uncertainty of the electron's position. In real measurements, the error of the "measuring device" is also introduced, which makes equality an inequality:

$$R_R \cdot mV_R \geq \hbar, \tag{51}$$

which explains the meaning of the experiments interpreted as the uncertainty of the electron position. With an increase in the momentum mV_R of the ring, the uncertainty in the measurement of the coordinate decreases, as the radius R_R of the ring decreases; this corresponds to the experiment.

8.2 Electron dimensions

Modern physics believes that an electron is an object no larger than $\sim 10^{-16} cm$. But ideas about such dimensions are incompatible with experiments on measuring the spin of an electron. A simple calculation shows that a rotating ball of such a radius can have a moment of momentum $\hbar/2$ only if the speed of rotation on the surface of the ball is many times higher than the speed of light. The real way out of this impasse is to accept the idea that the size of the electron is several orders of magnitude larger than $\sim 10^{-16} cm$. The presented concept naturally overcomes this contradiction. The vortex field in an ideal medium theoretically extends to infinity, so the momentum of the vortex in the ether is quite large.

Since an electron is not a ball, but a vortex ring, it is not enough to set one size for it; at least two values are needed:

1) The radius R_R of the ring. Formula (40) establishes a correspondence between the circumference $2\pi R_R$ of the ring and the de Broglie wavelength λ. Thus, according to the presented concept, the circumference of the ring is a quantity called by quantum mechanics "de Broglie wavelength".

2) The radius of the vortex core r_0. It is this value that is determined in experiments on measuring the size of an electron by the collision method. Collisions occur at any of the points of the circumference of the ring, so the measurement is not of the radius of the ring R_R, but of a much smaller magnitude r_0, that is, the magnitude $\sim 10^{-16} cm$.

8.3 Wave properties of an electron

The wave properties of an electron are explained based on the model of an electron as a vortex ring in the ether. A vortex ring is an elastic system in which vibrations can occur that can propagate along the perimeter of the ring. Since an integer number of standing waves should fit on the circumference of the ring, it

automatically follows that the circumference of the ring should be a multiple of the wavelength of the electron. The ratio (40) determines the wavelength of the first harmonic of de Broglie waves. For the wavelengths λ_i of the subsequent harmonics, we have:

$$2\pi R_R \equiv n\lambda_i. \tag{51}$$

The reason for the experimentally observed wave properties of the electron are the wave processes occurring inside the structure of the electron as a vortex ring.

8.4 Electron spin

One of the experimental facts contributing to the rejection of physics in the 20s of the XX century from visual models was the detection of electron spin. The experiment proves that there is some kind of rotation inside the structure of the electron, since there is a moment of momentum. However, attempts to understand this rotation visually, like the rotation of a spinning ball, have failed completely. Spin has properties that cannot be explained in principle within the framework of the concept of the opposition of matter and vacuum; explanations are possible only on the basis of continuum mechanics. Let's consider two properties of spin that have no explanation in quantum mechanics, but receive simple explanations in the theory being presented:

1) An abnormally large value of the electron's own angular momentum (spin), equal to $\hbar/2$;

2) The projection of spin on the direction of the magnetic field takes only two values: $+\hbar/2$ and $-\hbar/2$.

If we consider (as quantum mechanics considers) an electron to be an object whose size does not exceed $\sim 10^{-16} cm$, then a visual explanation of property 1) is impossible. As noted above, in the section "Electron dimensions", in order for a ball of this size to have a moment of momentum $\hbar/2$, it must rotate so fast that the speed on the surface of the ball must exceed the speed of light by almost five hundred thousand times. Such an assumption destroys the SRT. The only real way out is to assume that the size of the electron is several orders of magnitude larger. Such a hypothesis contradicts quantum mechanics, but is in agreement with the theory stated, according to which an electron is a vortex in an ideal medium. The vortex field extends theoretically to infinity, decreasing according to a certain law. According to (39), the momentum K of the vortex is equal to the reduced Planck constant $\hbar$. In [2], the angular momentum of the vortex in the ether was calculated using the Mathcad program. A formula for calculating the angular momentum of a vortex in the ether is obtained

$$K \equiv \hbar = \int_{\tau} \left|(\boldsymbol{\eta} - \boldsymbol{\eta}') \times \mathbf{q}\right| \cdot d\tau \qquad (52)$$

where $\mathbf{q}$ is the momentum density of the medium at a given point; $\boldsymbol{\eta}$ is variable vector radius of the considered point of the medium performing rotational motion; $\boldsymbol{\eta}'$ is the vector radius of the points of the circle of the ring around which rotation occurs; τ is the volume in which the movement occurs.

When entering the data included in (52), the Mathcad program calculates the value of the integral. In addition to creating a technique for calculating the spin of an electron, this example shows that ***the integral of the angular momentum of a vortex in the ether converges***. This result is of particular importance due to the fact that, as is known, the integrals of the angular momentum in the ideal fluid of the Eulerian model diverge [5, p. 200]. The analysis of the reasons for the convergence of integral (52), carried out in [2], shows that the momentum density in an ethereal vortex decreases faster with an increase in the radius of rotation than the momentum density in a vortex in an Eulerian fluid. The convergence of the vortex angular momentum integral in the ether proves that the ether, that is, the world medium of the presented model, is the only ideal medium in which the vortex angular momentum integral converges.

Let's consider how the theory explains property 2. The experimental detection of this property of the electron spin has put physics into a stupor. This property means that the electron spin vector does not precess when an electron enters a magnetic field (Stern and Gerlach, 1922). If we consider an electron to be a rotating object of the ball type, then such a property is impossible: any rotating object under the action of a force tending to change the position of the axis of rotation precesses. This was one of the reasons that physics, after futile attempts to explain this fact, announced that spin is a "purely quantum property" that cannot have a visual explanation. However, from the standpoint of the structure of the electron as a vortex ring, this property has a rational explanation. There are rotating elements inside the electron structure, but due to the closure of the vortex line, the sum of projections of elementary moments of momentum on any axis is zero. Therefore, the electron – vortex ring is oriented in a magnetic field without precession, and then one of the halves of the vortex line is "captured" by a magnetic field. From this interpretation of spin, an unambiguous conclusion follows that ***the spin of a free electron is zero; the moment of momentum occurs only when the ring hits the magnetic field***. This process is described in [2].

9 Mechanical models of electromagnetism

Usually, courses in electromagnetism and quantum mechanics first expound electromagnetism, and then quantum mechanics as "a doctrine more complex than electromagnetism". From the standpoint of the stated concept, on the contrary, the theory of the structure of an electron as a single object should be stated earlier, since it is simpler than the theory of electromagnetism as a theory of group behavior of electrons.

9.1 Electrostatics

In the Maxwell-Lorentz theory (hereinafter referred to as M-L theory) of electromagnetism, there are absurdities and absurdities, that is, difficulties of a fundamental nature. One of such difficulties is the "point charge paradox", according to which the intrinsic electric energy of an elementary charge is infinite. There is no such absurdity in the theory being presented.

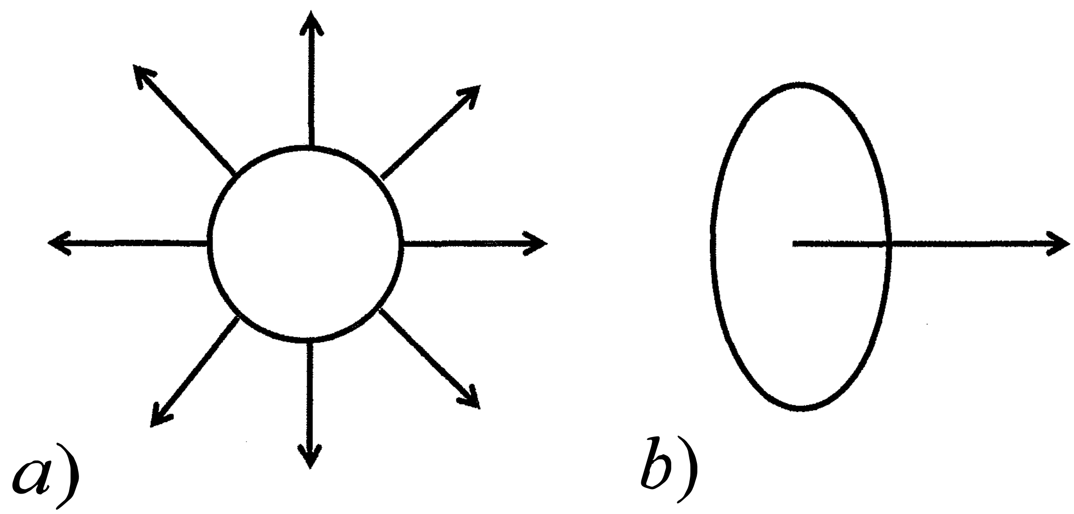

Fig. 6: Geometric structure of the elementary charge: a) in the Maxwell-Lorentz theory; b) in the theory being presented.

In the M-L theory, an elementary electric charge is geometrically similar to a macroscopic charged ball (Fig. 6). In the theory presented, an elementary charge – electron is a vortex ring in the ether that is, geometrically it represents one line of force orthogonal to the plane of the ring. Let's consider how a charged ball is formed on the basis of such a spherically asymmetric structure.

Suppose there is a conducting body, for example, a copper ball, in which an excess of such vortex rings is created (Fig. 7). Due to their ability to self-move, the rings tend to the surface of the ball, stop on the surface and create a vector field in

the surrounding space. The field of each ring is described by the expression (34). The total field is equal to the vector sum of the fields of all rings. There is a theorem of hydrodynamics, also applicable in electrodynamics, according to which the vector sum of fields created by dipoles distributed over a sphere is zero [5, p.291], [11, p.73], that is

$$\oint_{\sigma}\left[-\frac{C}{4\pi}\nabla\int_{\Sigma}\frac{\partial}{\partial n}\left(\frac{1}{r}\right)d\Sigma\right]d\sigma=0, \tag{53}$$

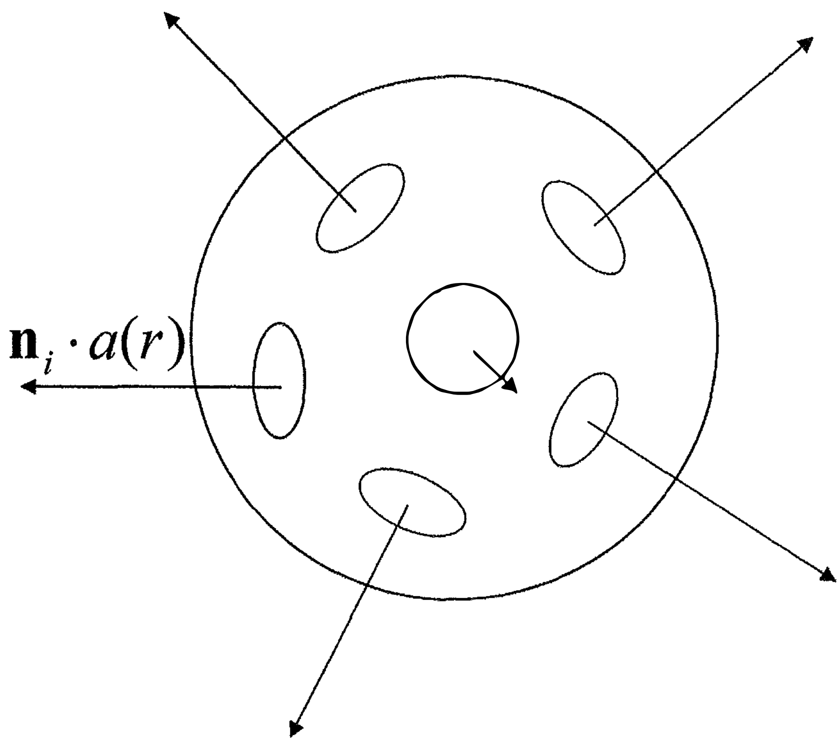

Fig. 7: Formation of a spherically symmetric charged ball based on spherically asymmetric elementary charges

where Σ is a surface resting on the contour of the ring; σ is a closed surface over which the vortex rings are distributed. Consequently, the first terms in the right part of relation (34) mutually compensate each other. Thus, the field around the ball is equal to the geometric sum of the vectors $\mathbf{a}_{//EM}$ created by each ring. This is the electrostatic field.

It is shown in [2] that bodies "charged" with such vortex rings interact with each other in full accordance with the experiment. Bodies charged with rings of the same type repel each other, charged with rings of opposite types attract. The empirically obtained Coulomb's law is analytically proved.

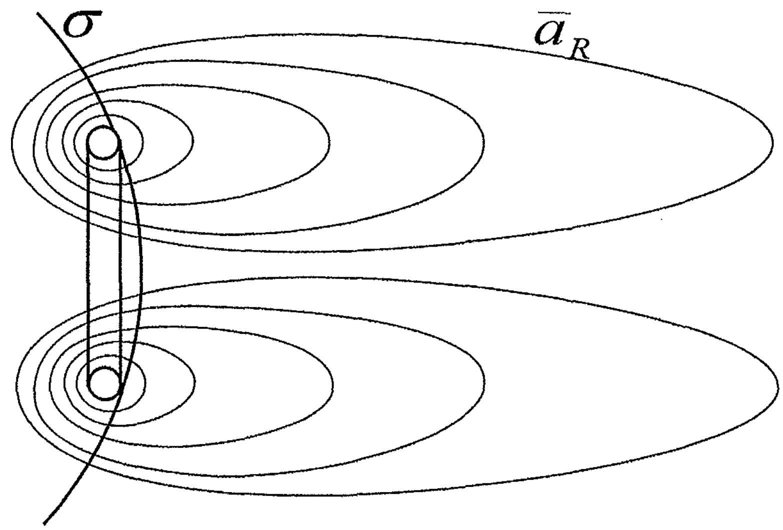

Fig. 8: Image of the ring field stopped on the surface of a charged body. If a connection is imposed on the translational motion of the ring, then forces arise that stretch the field of the ring in the direction of the stopped movement

Let us briefly consider the physical picture of the process of charging the ball (in the M-L substantial theory, this process is called the process of electric displacement). Fig. 8 shows one vortex ring stopped on the surface of the ball. The ring cannot go beyond the ball due to the presence of a cavitation cavity in the center $O`$ of the vortex, but for the vector $\mathbf{a}$ field, due to the superfluidity of the medium, obstacles cannot exist. Since the translational velocity V_R becomes zero, the centrifugal force $d\mathbf{F}_{CF}$ disappears and the compression of the ring begins. But the movement of vortex lines in the direction of the center O of the ring generates force $d\mathbf{F}_{CF}$ (analogous to the Zhukovsky force) acting in the direction of the stopped

translational motion of the ring. This force stretches the ring field in this direction. The energy of the translational motion of the ring is transformed into the energy of elastic deformation of the field.

Each ring, according to (35), gives a contribution to the total field of the vector $\mathbf{a}_{//EM}$ in the surrounding space. Spreading the integral (35) over the entire surface σ of the sphere, we obtain the Gauss theorem:

$$Ne = \oint_{\sigma} \mathbf{a}_{//EM} \cdot \mathbf{n} \cdot d\sigma \tag{54}$$

Therefore, in the mode of electrostatics, the vector $\mathbf{a}_{//EM}$ corresponds to the vector of the electric field strength $\mathbf{E}$ of the M-L theory

$$\mathbf{a}_{//EM} \sim \mathbf{E} \tag{55}$$

Obviously, the Gauss theorem (54) is valid only in such an integral form, the transition to an infinitesimal volume is impossible. Therefore, the "point charge paradox" does not exist in this theory.

The "electric force" generated by the vortex ring when stopped can be easily calculated. To do this, consider the force $\mathbf{G}$. As follows from the definition (25), the value G is the rest energy density of the electron – vortex ring per unit length of the vortex line:

$$G = \int_{\sigma} (p_0 - p) \cdot d\sigma = \int_{\sigma} \varepsilon \cdot d\sigma = E_{kin} / 2\pi R_R \tag{56}$$

A centripetal force acts on each element dl of the ring, which can be calculated by the formula (26). When the ring is compressed, the force acting on each element of the ring is transformed into force acting in the direction of the stopped movement. Therefore, the total "electric force" F_{EL} with which the vortex ring presses on the barrier:

$$F_{EL} = G \cdot 2\pi = (E_{kin} / 2\pi R_R) \cdot 2\pi = m_0 c^2 / R_R \tag{57}$$

Where E_{kin} is the kinetic energy of the ether in the vortex ring, that is, it is the rest energy of the electron

$$E_{kin} = m_e c^2 = 0,511 \cdot 10^6 eV$$

The magnitude of the electric force depends on the radius R_R of the ring, that is, on the energy of the translational motion of the ring. We calculate this force for a ring with the maximum energy of translational motion, that is, a ring whose velocity tends to magnitude c. Substituting the value c in (41) instead of the velocity V_R, we obtain the reduced Compton wavelength $\bar{\lambda}_C$

$$R_{R\min} = \hbar / m_e \cdot c = \bar{\lambda}_C = \lambda_C / 2\pi \tag{58}$$

Substituting this value in (57), we get the value of the "electric force":

$$F_{EL}(R_R = \bar{\lambda}_C) = 1{,}6 \cdot 10^{-19} \cdot 0{,}511 \cdot 10^6 J / 3{,}86 \cdot 10^{-13} m = 0{,}21N \qquad (59)$$

Since this force is applied to the particle by mass $m_e = 0{,}91 \cdot 10^{-30} kg$, it is, without exaggeration, a gigantic force. The reason for such a large amount of electrical interaction is that, according to (57), the rest energy of the particle takes part in the genesis of the electric force. For low-energy electrons, this force is much less. Let's calculate, for example, the electric force for an electron with the energy $50eV$ of translational motion. To do this, we calculate the radius of the vortex ring at such energy. The radius of the ring is calculated by the formula for the de Broglie wave:

$$R_R = \frac{\hbar}{m_e V_R} = \left| V_R = \sqrt{2E_{//} / m_e} \right| = \frac{\hbar}{\sqrt{2m_e E_{//}}} \qquad (60)$$

Substituting the value of the mass-energy of the electron, that is, the kinetic energy E_{kin} of the ether in the vortex ring, we get:

$$F_{EL} = G \cdot 2\pi = (E_{kin} / 2\pi R_R) \cdot 2\pi = m_e c^2 / R_R = m_e c^2 \sqrt{2m_e E_{//}} / \hbar$$

$$F_{EL} = \frac{9{,}1 \cdot 10^{-31} \cdot 9 \cdot 10^{16} \sqrt{2 \cdot 9{,}1 \cdot 10^{-31} \cdot 50 \cdot 1{,}6 \cdot 10^{-19}}}{1{,}05 \cdot 10^{-34}} = 2{,}976 \cdot 10^{-3} (N)$$

9.2 Permanent magnetic field

From the standpoint of the theory presented, there are no separate "entities" – an electric field and a magnetic field: these fields are different manifestations of the same vector $\mathbf{a}_{//EM}$. In the electrostatics mode, the vector $\mathbf{a}_{//EM}$ creates such a state of the medium in the space around the charged ball, which at the macroscopic level is perceived as an electrostatic field. In DC mode, the vector $\mathbf{a}_{//EM}$ takes a different form.

Consider the picture of the creation of a magnetic field. Suppose there is a closed conducting circuit in which, with the help of a current source, the axes of the vortex rings are oriented along the contour in any one, certain direction of circumvention of the contour. Fig. 9 shows a rectilinear segment of this closed contour. We consider all rings to be the same, and we also consider the distances between the rings to be equal. The cores of the rings are fixed in place by means of external barriers, and the fields of the rings move freely in the surrounding space.

Thus, in this concept of a magnetic field, vortex rings – electrons do not move along a conductor. As shown in section 5, under these conditions, each ring creates a satellite flow, that is, a vector $\mathbf{a}_{//EM}$ flow. Satellite streams circulate through a closed

current loop at a speed of c. The field of each ring is described by the relation (34) for the vector $\mathbf{a}_{R2i}$. The total vector field at any point P outside the wire is equal to the sum of the vectors $\mathbf{a}_{R2i}$ created by all the rings:

$$\mathbf{a}(P) = \sum_{i}^{N} \mathbf{a}_{Ai} + \sum_{i}^{N} \mathbf{a}_{//EMi} \,. \tag{61}$$

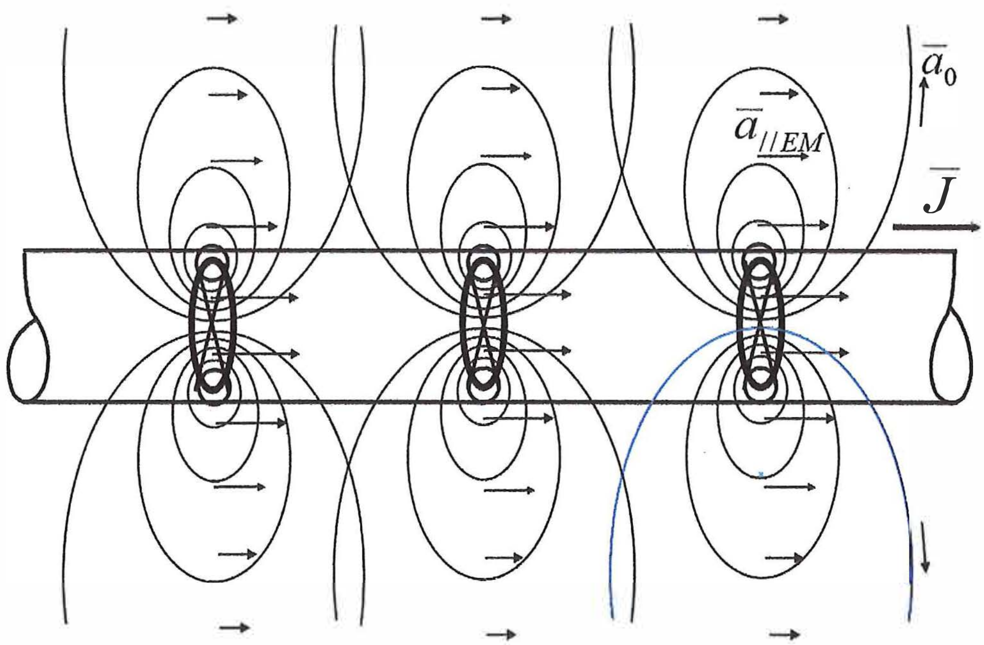

Fig. 9: Image of a rectilinear segment of a contour with a current. The rings inside the conductor represent vortex rings-electrons; oval lines represent the lines of the potential vector $\mathbf{a}_A$; arrows parallel to the conductor represent the vector $\mathbf{a}_{//EM}$. The barriers superimposed on the translational velocities of the rings are represented by crossed rectilinear segments

However, a theorem can be proved that the first term in (61) is zero, that is, the sum of the potential components of the fields of all dipoles is zero. Let's prove this theorem. Consider the first sum on the right side. The vector $\mathbf{a}_A$ has potential Φ. The potential created by the i-dipole (for simplification, we consider the rings to be single dipoles) at the point P

$$\Phi_i = -\frac{C}{4\pi}\nabla\left(\frac{1}{r_i}\right)\cdot\mathbf{n}_i\ , \tag{62}$$

where $\mathbf{r}_i$ is the radius vector drawn from the point P to the point where the vortex ring is located. The total potential Φ_{SUM} created by all rings at a point P :

$$\Phi_{SUM} = -\frac{C}{4\pi}\sum_i^N\nabla\left(\frac{1}{r_i}\right)\cdot\mathbf{n}_i\,. \tag{63}$$

With a large number of rings, the direction of the normal $\mathbf{n}_i$ to the plane of the ring tends to the direction of the element of the contour length $\Delta\mathbf{l}_i \equiv \Delta\mathbf{r}_i$, and the sum tends to the integral, which takes the form of circulation:

$$\Phi_{SUM} = -\frac{C}{4\pi}\oint_L\nabla\left(\frac{1}{r}\right)\cdot d\mathbf{l} = 0\,, \tag{64}$$

where L is a closed current loop. This integral is zero as the circulation of the potential vector $\nabla\left(\frac{1}{r}\right)$. Therefore, the vector $\mathbf{a}$ field at a point P is equal to the sum of the vectors $\mathbf{a}_{//EM}$ created by all the vortex rings flowing through the conductor:

$$\mathbf{a}_\Sigma(P) = \sum_i^N\mathbf{a}_{//EMi}\,. \tag{65}$$

The total field of vectors $\mathbf{a}_{//EM}$ distributed in space around a wire with a current is a magnetic field. Therefore, in the described concept of electromagnetism, the electric current is not localized within the conductor. Current is the movement of satellite energy flows, theoretically extended to infinity. Each electron – vortex ring creates a single satellite flow. The vector $\mathbf{a}_{//EMi}$ taken with a minus sign is a vector of the "current density $\mathbf{j}_i$" created by one electron:

$$\mathbf{j}_i = -\mathbf{a}_{//EMi} \tag{66}$$

The minus sign on the right side (66) is introduced because, according to the notation accepted in physics, the positive direction of the current is the direction of movement of positive charges. Since the direction of the vector $\mathbf{a}_{//EM}$ coincides with the direction of motion of the electron, that is, the "negative charge", then, consequently, the directions of the vectors $\mathbf{a}_{//EM}$ and $\mathbf{j}$ are opposite.

The law of vector $\mathbf{a}_{//EM}$ distribution in the space around the conductor is similar to the law of vector potential $\mathbf{A}$ distribution in M-L theory

$$\mathbf{a}_{//EM} \sim \mathbf{A} \tag{67}$$

Each elementary current J_i represents the power of the vector $\mathbf{a}_{//EM}$ flow through an infinite plane Σ normal to the conductor:

$$J_i = -\int_{\Sigma} \mathbf{a}_{//EMi} \cdot \mathbf{n} \cdot d\sigma \tag{68}$$

Comparison of expressions (68) and (35) shows that in this model of electromagnetism, the quantities "current J" and "charge e" have the same dimension. The elementary current J_i created by a single electron – a vortex ring, is a quantity called "electron charge e" by physics. The total current J_{SUM} through the plane Σ is equal to the sum of all elementary currents:

$$J_{SUM} = -\sum_{i}^{N} \int_{\Sigma} \mathbf{a}_{//EMi} \cdot \mathbf{n} \cdot d\sigma = -\int_{\Sigma} \mathbf{a}_{//EM} \cdot \mathbf{n} \cdot d\sigma \tag{69}$$

Thus, the force vector in this concept is a vector $\mathbf{a}_{//EM}$. Instead of the magnetic field strength $\mathbf{H}$ lines of the M-L theory, which are orthogonal to the conductor, in the theory being presented, the magnetic interaction is determined by vector $\mathbf{a}_{//EM}$ lines that are parallel to the conductor. Such a magnetic field model brings the theoretical description of the magnetic interaction into line with experimental facts. One of the facts of the discrepancy between the M-L theory and the experiment is the description of the interaction of magnetic fields of parallel conductors.

Fig. 10 shows two parallel conductors with currents and images of the magnetic fields of these currents based on the M-L theory and the theory being presented. In the M-L theory, magnetic fields are described using a vector $\mathbf{H}$, in the theory being presented using a vector $\mathbf{a}_{//EM}$. It is shown in [2] that if one strictly follows the M-L theory, then there is no correspondence between the theory and the experiment:

1) According to the M-L theory, the conductors will not attract, but repel;

2) The force of interaction between the conductors is proportional not $1/d$ (as the experiment gives), but $1/d^2$, where d is the distance between the conductors.

The inability of a theoretical explanation of the magnetic interaction from the standpoint of M-L theory is indicated by Whittaker [12, p. 375]. Therefore, in the modern formal mathematical theory, the "explanation" of the interaction of conductors is not based on the M-L theory, but on the basis of the empirical Ampere formula:

$$dF_{12} = \frac{\mu_0}{4\pi}\frac{J_1 J_2}{d} dl, \text{ (Ampere)} \tag{70}$$

where J_1, J_2 are currents in the conductors according to M-L theory.

From the standpoint of the theory being presented, the geometry of the fields becomes clear. With parallel conductors, the vectors $\mathbf{a}_{//EM}$ created by these conductors are also parallel. An area of reduced pressure is created in the area between the conductors, so the conductors are attracted.

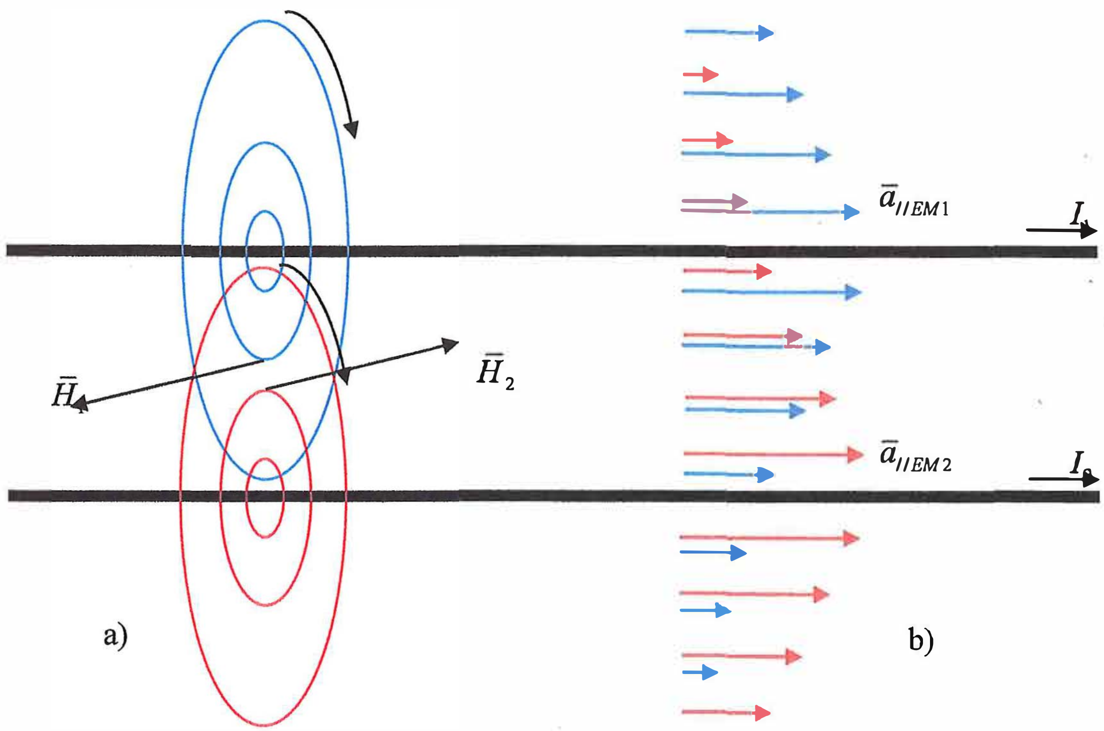

Fig. 10: Image of the magnetic field of parallel conductors: a) based on the M-L theory, using vectors $\mathbf{H}$; b) based on the theory presented, using vectors $\mathbf{a}_{//EM}$. Vectors related to conductor 1 are shown in blue; those related to conductor 2 are shown in red

There are no such inconsistencies in the theory presented, and the empirical Ampere formula (70) has been proved analytically [2, p. 284]. Thus, despite the strangeness of the presented models and their difference from the usual images of fields in the M-L theory, the presented models have such theoretical and experimental confirmations that the M-L theory cannot compete with. There are nonsenses and absurdities in the M-L theory, that is, fundamental difficulties that cannot be solved within the M-L concept. Let's list the main of these difficulties.

1) There are no mechanical models of phenomena;
2) The existence of the point charge paradox;
3) The force of interaction between conductors with current (Ampere force) is calculated not according to the M-L theory, but according to the empirical Ampere formula.

9.3 The nature of radiation

If we remain within the framework of reality, that is, we assume that all phenomena can be understood visually, and then two concepts of the physical nature of radiation are possible: 1) light and other EM radiation are particles flying in the void; 2) light are waves propagating in some medium. The theory being presented considers light to be waves in world medium, however, unlike Maxwell's abstract model, it operates with real mechanical quantities. In addition, the proposed theory explains the phenomenon of radiation quantization, that is, the experimental fact that radiation occurs in portions, quanta.

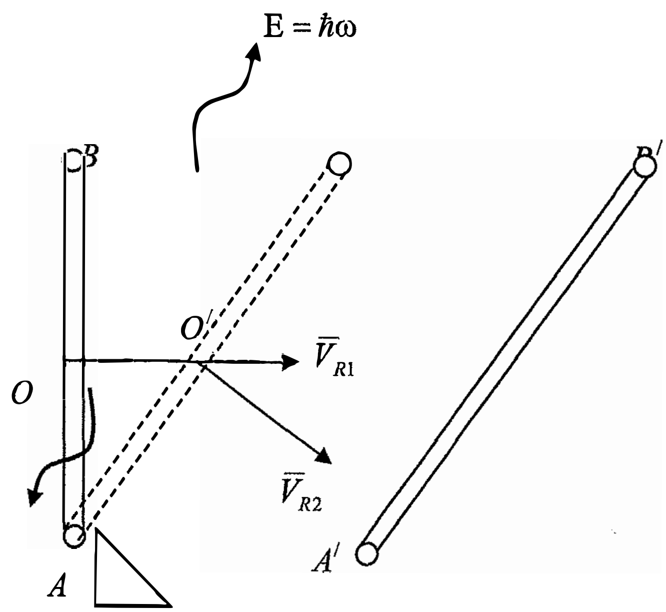

Fig. 11: Simplified image of the vortex ring during radiation.

Let us briefly consider the physical principles on which the explanation of the radiation process is based; for a more complete explanation, see [2]. Formula (29)

proves that in an ideal medium there is a circulation of surface forces along the contour of the vortex ring. Due to the curvature of the vortex line, a force directed to the center of the curvature of the vortex line acts on each element dl of the ring. The same principle underlies the proposed model of propagation of light and other electromagnetic oscillations. Just as the curvature of the ring element dl creates the ability of the ring to self-move, the curvature of the emerging element of the vortex line creates a force with which this element acts "on itself".

Let's construct a general picture of the radiation mechanism. Radiation occurs when the ring loses kinetic energy. The radiation energy E_{RAD} is the part of the kinetic energy that is released when the velocity of the ring decreases from the initial velocity $\mathbf{V}_{R1}$ to the final velocity $\mathbf{V}_{R2}$:

$$E_{RAD} = E_{KIN1} - E_{KIN2} \tag{71}$$

That is, the first condition of radiation is the braking of the ring. The second necessary condition is the rotation of the ring plane during braking, so the whole process can be defined as "asymmetric braking".

Let the vortex ring move at a speed $V_{R1} << c$ (Fig. 11). At the moment of time t_1, the circumference of the ring meets an obstacle at a point A and the process of asymmetric braking begins. When hitting an obstacle, the speed of the ring element at the point A decreases to a certain velocity $V_{R2} < V_{R1}$. However, the velocity V_{R2} is not transmitted instantly to the entire ring: the point B diametrically opposite to the point A continues to move in a straight line. Since the point B is ahead of the point A in translational motion, it can be simplistically assumed that the plane of the ring rotates around the axis passing through the point A. The decrease in speed moves along the circumference of the ring in the form of deformation. At this time, there is a process of radiation into the region of space enclosed between the former and the new positions of the plane of the ring. Figure 11 shows the initial and final phases of the process. During the asymmetric braking, the ring plane rotates around the axis passing through the point A by an angle θ_{rad}. At the moment of time t_2, the deformation reaches a point B. The rotation of the ring plane ends, and along with the rotation, the radiation process ends and the ring continues to move freely, but at a lower speed V_{R2} and in a different direction.

As you know, there is no visual model of radiation in modern physics; the process is described only formally. The presented model, despite its simplified, sketchy nature, provides a visual explanation of the radiation frequencies, as well as the quantum nature of the radiation. The portionality of the radiation is an organic consequence of the deformation movement along the perimeter of the ring. When the deformation reaches the point B, the radiation stops. On this basis, the Planck

formula for radiation can be analytically obtained. Let's write the formula (41) in the following form:

$$mV_R = \frac{\hbar}{R_R}$$

Multiply both parts of this equality by the speed differential dV_R and integrate from the initial speed V_{R1} to the final speed V_{R2}. We will get:

$$m\int_{V_{R1}}^{V_{R2}} V_R \cdot dV_R = \hbar \int_{V_{R1}}^{V_{R2}} \frac{dV_R}{R_R}.$$

The integrand on the right side is the doubled differential of the angular velocity of rotation of the plane of the ring around the point A:

$$\frac{dV_R}{R_R} = 2 \cdot d\omega$$

Therefore, it is possible to replace the variable in the right part:

$$m\int_{V_{R1}}^{V_{R2}} V_R \cdot dV_R = 2\hbar \int_{\omega_1}^{\omega_2} d\omega$$

As a result of integration, we have

$$E_{RAD} = \frac{mV_{R1}^2}{2} - \frac{mV_{R2}^2}{2} = \hbar \cdot 2(\omega_1 - \omega_2) \qquad (72)$$

The ratio (72) can be written in the following form:

$$E_{RAD} = \hbar \cdot 2(\omega_1 - \omega_2) = \hbar \cdot \omega_{RAD} \qquad (73)$$

This is a complete analogue of Planck's formula on the discrete nature of radiation:

$$E_{RAD} = \hbar \cdot \omega_{RAD} \quad \text{(Planck, 1900)} \qquad (74)$$

Relationship (74) clearly shows the mechanical meaning of the quantities characterizing radiation. The plane of the vortex ring rotates with a variable angular velocity ω. The angular frequency ω_{RAD} of the emitted quantum makes sense of the doubled difference of the angular velocities of rotation at the beginning and at the end of the act of radiation

$$\omega_{RAD} = 2(\omega_1 - \omega_2) \qquad (75)$$

10 Conclusion

The history of physics is the history of the expulsion of substantial quantities from science and the explanation of the nature of these quantities by mechanical motion. "*From the totality of these new trends, the ultimate goal of the development*

of physics is becoming clearer – the creation of a unified science of physics as the mechanics of all matter, as the kinetics of all material movements ". [13, p. 189]. The most striking example on this path is the explanation of the physical nature of heat by mechanical motion and the expulsion from science of "caloric substance" as an alleged source of thermal phenomena. The substantial theories that existed in physics described processes mathematically well enough, but did not construct visual models. Instead of models, it was assumed that there was some "fantastic substance" that had the necessary properties and did not possess any other properties. Substantial theories are the initial methods of describing phenomena and, despite their natural philosophical fallacy, are useful and necessary for science. However, we must always remember that the substantial theory is a temporary, initial stage of the physical theory, which will be replaced by the stage of constructing a model of the phenomenon. The construction of a model of phenomena opens up new horizons for the development of science. For example, the knowledge of the essence of heat made it possible to construct an absolute temperature scale and on this basis build a new, wide field of low temperature physics.

Explanation of the nature of electric charge by mechanical motion was the goal and task of physics of the XIX century, including the great physicists W. Kelvin, J. Maxwell, G. Helmholtz. However, in the XIX century this problem was not solved. Kelvin, describing Maxwell's theory of electromagnetism, said that this theory is a step back from completely defined mechanical concepts.

At the end of the XIX - beginning of the XX century, such properties of matter were experimentally discovered, which, according to the creators of the new physics, could not be understood within the framework of mechanics. At the same time, most of the scientists of the older generation in the natural philosophical sense remained in the same positions, although they could no longer offer a constructive physical theory. The science of the XX century, considering the failure of the physics of the XIX century in the construction of mechanical models of electromagnetism, decided that the construction of such models is impossible. The desire for mechanical models is declared "naive mechanicism". Therefore, physical problems are solved formally and mathematically.

According to the author, it is the desire to know the Universe without models that is naive; this leads to the unrestrained growth of esoteric "entities" in science. The modern science of Nature is no longer physics; this teaching can be called "selected chapters of mathematics for the abstract description of experimental facts." Therefore, there are, for example, such esoteric "explanations" of phenomena, according to which "an electron has its own moment of momentum, but this moment of momentum is not due to rotation."

Only the construction of models gives a real understanding of phenomena and expels esotericism from science. The presented concept shows that the construction of a mechanical model of an electric charge is possible. The solution to this problem lies beyond the search of the creators of physics of the XX century. To solve the problem, a large-scale revision of physical representations is necessary, starting with Newton's physics. Substantial quantities are not only "charge", but also the quantities "mass" and "time". At the same time, the proposed concept negates the basic methodological idea of modern abstract physics, which consists in the fact that "the more complex the mathematical theory, the more accurately it reflects the structure of the Universe." It is shown that the mathematical description of the world medium of this model is even simpler than the theory of continuous media.

The desire of a rationalist scientist for a mechanical explanation of all phenomena is indestructible. There is a growing rejection of abstract mathematical physics in the scientific community and a craving for a visual, model understanding of the essence of phenomena [14]. Expressing full agreement with this aspiration, it should be noted the following. All these attempts at explanation occur within the framework of either correction or modernization of Newton's mechanics. As follows from this work, the solution to the problem lies much deeper – not at the level of tactics of cognition, but at the level of strategy, that is, at the level of philosophy. Newton's physics, strictly, is not mechanics at all, since there are substantial quantities in it. Mechanics is only a physical theory, which is based on the world medium – ether, since such a theory is described using only mechanical quantities.

The construction of mechanical models of the genesis of the quantities mass, time, charge completes the mechanical explanation of the fundamental concepts of physics. Thus, the goal set by W. Thomson (Introduction) has been achieved or, at least, the direction of movement towards this goal has been determined.

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RADIATION THERAPY TREATMENT OF VARIABLE CANCER CELLS ON THE BASIS OF SCATTERING

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Abstract

The aim is to study the scattering phenomena (cross-section) on radiation therapy treatment on the basis of the mass attenuation coefficient (MAC) of the element, oxides, and alloys of Ruthenium (Ru), Gadolinium (Gd), Bismuth(Bi), and Gold (Au). This is because these elements oxides and alloys are the best group of anticancer agents. To study the scattering and MAC authors take data from XCOM online software provided by NIST as open-source. The studies show that one can select the anticancer agent on the basis of the size of the tumor i.e. for small and large. On comparison of MAC of considered elements, oxides, and alloys it was found that MAC is different for the same incidence energy of the photon. In alloy, the MAC of Bi&Ru is lower while Gd&Au is higher, in oxides MAC of RuO_2 is lower and Bi_2O_3 is higher while in Ru is lower and Bi is higher. Since cross-section is directly proportional to MAC. Therefore, a larger cross-section during the interaction is used to treat larger cancer cells while small cross-sections are used to treat small cancer cells. In this way, one can select radiation therapy for various sizes of cancer cells.

Keywords: Mass attenuation coefficient, cross-section, anticancer agent, scattering, radiation therapy.

1. Introduction

The beam energy is one of the major factors influencing the radiation therapy effectiveness. In radiation therapy of tumors loaded with high-Z elements the physical concepts of photoelectric interaction has been employed for photon energy selection. In other words, it is physically obvious that the possibility of photoelectric interaction is raised when the photon energy is just above the k-edge of high-Z elements. Biston et al. used a combination of synchrotron irradiation and cis-diammine dichloroplatinum (II) on rat F98 glioma cells below and above the K-edge of platinum (78.4 keV). Surprisingly, the results were identical for both cases. The suggested reason for such a strange event was that for an incident photon with the energy of K-edge, all the energy is spent to eject K-electron and the photoelectron would not receive enough energy to result in excessive damage to surrounding material. Today, cancer patients who have access to the health care system are treated by a surgeon, a radiation oncologist, a medical oncologist or, preferably, a multidisciplinary team. Brachytherapy is the administration of radiotherapy by placing radioactive sources adjacent to or into tumours or body cavities. Currently, the use of artificially produced radionuclides such as 137Cs, 192Ir, 198Au, 125I and 103Pd is well established [1].

In X-ray external radiation therapy, low energy beams (until 200 kV) have very few applications and are dedicated to skin treatments (< 5 mm in depth, e.g. melanoma, basal cell carcinoma. Medium energies 200 keV to 1 MeV (ortho voltage and super voltage X-rays) were widely used for shallow treatments since the 1930's – 1940's but became less advantageous at the advent of high-energy electrons during the 1960's - 1970's. Nowadays, high-energy beams, also called megavoltage beams, (1 to 25 MeV) are by far the most commonly used as they allow the treatment of deep tumors (> 2 cm in depth). Cell damages following interactions between X-rays and high-Z NPs mostly result from the photoelectric effect which is prevailing until the photon energy reaches 500 keV (e.g. for Au). Moreover, the medium- and high-energy components should theoretically interact with matter (here in high-Z NPs and biological matter) by the Compton effect, therefore releasing lower energy photons. These latter, depending on their energy, trigger in turn either photoelectric or Compton effects.

Radiotherapy is currently an essential component in the management of cancer patients, either alone or in combination with surgery or chemotherapy, both for a cure and for palliation. The cancer patients who are cured, it is

estimated that 49% are cured by surgery, about 40% by radiotherapy alone or combined with other modalities, and 11% by chemotherapy alone or combined [2]. Clearly, ionizing radiation in sufficient doses has a cell-killing effect, but it is not specific enough to differentiate between cancerous and normal cells. Strategies had to be found to improve the therapeutic index, either by physically improving target conformity or by increasing the radiation sensitivity of the cancer cells relative to the normal cells. In combination with the technological progress in radiation oncology, this new knowledge offers the potential to develop more specific targeted therapeutic strategies to optimize the curative principle of radiotherapy in the near future [3]. In addition, cancer genome analysis is expected to have a far-reaching impact on our understanding of cancer biology and will likely prompt new approaches to the detection, diagnosis, treatment and possibly prevention of the disease [4].

2. Literature Review

The X-ray interaction with high-Z gold nano-particle (GNP) and subsequent mechanisms which lead to dose enhancement should be explained for further applications. Based on the energies of ionizing photons, different types of interactions occur between photons and GNPs. The photoelectric effect is the predominant process for photons with energy from 10 to 500 keV. The result of this process is the production of electrons, characteristic X-ray of gold atoms or auger electrons. In photoelectric interaction, between photons and GNPs, a vacancy in a K, or L, M shell following photoelectric absorption results in a de-excitation of the atomic system, either by characteristic X-ray or Auger-electron emission. For photons above 500 keV, the Compton scattering and excitation are observed. The Compton scattering will result in atom re-excitation and production of Compton electrons which leads to subsequent photoelectric effect. For photon energies higher than 1.02 MeV, pair production process dominates and results in positron and electron pairs. For all of these interactions, except Compton scattering, the cross section of photon interactions depends strongly on Z [5].

Over the last decades, many research programs dealt with in vitro and in vivo applications of NPs in radiation therapy. Given that radiation therapy is not a selective antitumor treatment, the main challenge for radiation oncologists, medical physicists and radiobiologists is to increase its therapeutic efficacy without increasing damages dealt to the surrounding healthy tissues. Hence, the goal of combining NPs with radiation therapy is to increase the differential effect between healthy and tumor tissues. Different mechanisms of interaction between X-rays and NPs are expected according to NPs

chemical nature. We could distinguish between (i) high atomic number Z, NPs that enhance the photoelectric and Compton effects (and thus the subsequent emissions of secondary electrons) to increase conventional radiation therapy efficacy; (ii) X-ray triggered drug-releasing NPs that, for instance, uses drug-loaded NP [6]. Under irradiation, the NP capsule is destroyed and the drug is released inside the targeted tissues. (iii) Self-lighting photodynamic NPs that are usually made of a lanthanide-doped high-Z core [7].

The most studied NPs are gold-based NPs (GNPs) that were widely described in particular by Hainfeld et al.in 2008. Recent studies have also reported the use of lanthanide-based NPs, titanium oxide nanotubes or cadmium selenide quantum dots [8]. For example, gadolinium-based NPs, besides their high-Z, offer an innovative approach due to their capacity to act as powerful contrast agents in MRI reported by Le et al in 2011. Interestingly, some authors used silver-based NPs to take advantage of its excellent surface enhanced Raman scattering and broad-spectrum antimicrobial activities reported by Liu et al. in 2013.
Gold nanoparticles have received a great deal of attention for cancer-related applications due to their ability to thermally affect and destroy cancerous cells, as well as their photothermal heating capacity and ease in surface functionalization. The main advantage is that when using gold nanoparticles, the heating only affects the site adjacent to the nanoparticles, without harming other healthy tissues or cells [9]. Cancer is rapidly becoming the top killer in the world. Most of the FDA approved anticancer drugs are organic molecules, while metallodrugs are very scarce. The advent of the first metal-based therapeutic agent, cisplatin, launched a new era in the application of transition metal complexes for therapeutic design. Due to their unique and versatile biochemical properties, ruthenium-based compounds have emerged as promising anti-cancer agents that serve as alternatives to cisplatin and its derivatives. The ruthenium(III) complexes have successfully been used in clinical research and their mechanisms of anticancer action have been reported in large volumes over the past few decades. Ruthenium (II) complexes have also attracted significant attention as anticancer candidates; however, only a few of them have been reported comprehensively [10].

Multifunction bismuth-based nanoparticles with the ability to display diagnostic and therapeutic functions have drawn extensive attention as theranostic agents in radiation therapy and imaging due to their high atomic number, low toxicity, and low cost. Herein, we tried to introduce multifunction bismuth gadolinium oxide nanoparticles ($BiGdO_3$) as a new theranostic agent for radiation therapy, computed tomography (CT) and

magnetic resonance imaging (MRI). *In vivo* results emphasized the radiosensitizing effect of $BiGdO_3$-PEG nanoparticles. Both bismuth and gadolinium provide CT contrast, while gadolinium can be employed for MRI T1 contrast, so we evaluated contrast enhancement of $BiGdO_3$-PEG nanoparticles as a dual-modal imaging agent in MR and CT imaging [11]. Nanoparticles containing high-Z elements are known to boost the efficacy of radiation therapy. Gadolinium (Gd) is particularly attractive because this element is also a positive contrast agent for MRI, which allows for the simultaneous use of imaging to guide the irradiation and to delineate the tumor. In this study, we used the Gd-based nanoparticles, AGuIX®. After intravenous injection into animals bearing B16F10 tumors, some nanoparticles remained inside the tumor cells for more than 24 hours, indicating that a single administration of nanoparticles might be sufficient for several irradiations. Combining AGuIX® with radiation therapy increases tumor cell death, and improves the life spans of animals bearing multiple brain melanoma metastases. These results provide preclinical proof-of-concept for a phase I clinical trial [12]. Application of scattering in diffrenet materials with and without laser field was study in more detail [13], [14], [15], [16].

3. Method and Materials

A narrow beam of mono-energetic photons in the X- ray region is attenuated to an intensity I from an incident intensity Io is passing through a material thickness with mass per unit area x, according to the well-established Beer-Lambert's exponential law

$$\frac{I}{I_0} = \exp\left(\frac{-\mu}{\rho}\right)x \tag{1}$$

In which μ/ρ is the mass attenuation coefficient and can be obtained from the measured I, I_0 & x data. The $\left(\frac{\mu}{\rho}\right)$ is the base value through which the parameters, such as effective atomic number (Z_{eff}), effective electron density(N_{eff}) can be achieved and MAC is defiend as

$$\frac{\mu}{\rho} = \sum_i w_i \left(\frac{\mu}{\rho}\right)_i \tag{2}$$

Where w_i and $\left(\frac{\mu}{\rho}\right)_i$ are the fractional weight and the total mass attenuation coefficient of the ith element in the material. The $\left(\frac{\mu}{\rho}\right)$ of the elements at

certain energies were acquired from XCOM program. This program is a very useful program; it gives the mass attenuation coefficient of the relevant element or compound in the energy range from 1 keV to 100 GeV. The dominant scattering process for 511 Kev photons is Compton scattering, where the incident gamma-ray strikes an atomic electron producing atomic ionization. The incident photon will scatter through an angle θ determined by the KIein-Nishina differential cross section equation,

$$\left(\frac{d\sigma}{d\Omega}\right)_a = \frac{Zr_e^2}{2}\left(\frac{1}{1+\alpha(1-cos\theta)}\right)^2 \left((1+\cos^2\theta) + \frac{\alpha^2(1-cos\theta)^2}{[1+\alpha(1-cos\theta)]}\right) \tag{3}$$

This equation is a differential atomic cross sectional area equation for K-N. Also, the total K-N cross section per atom can be written as:

$$\sigma_a = 2\pi \int_0^\pi \left(\frac{d\sigma}{d\Omega}\right)_a sin\theta d\theta \tag{4}$$

Where θ is scattering angle overall photons. Now from (3) and (4), we get:

$$\sigma_a = 2\pi \int_0^\pi \frac{Zr_e^2}{2}\left(\frac{1}{1+\alpha(1-cos\theta)}\right)^2 \left((1+\cos^2\theta) + \frac{\alpha^2(1-cos\theta)^2}{[1+\alpha(1-cos\theta)]}\right) sin\theta d\theta \tag{5}$$

On solving the total KN cross section per atom is obtained as:

$$\sigma_a = Z2\pi r_e^2 \left\{\frac{1+\alpha}{\alpha^2}\left[\frac{2(1+\alpha)}{1+2\alpha} - \frac{\ln(1+2\alpha)}{\alpha}\right] + \frac{\ln(1+2\alpha)}{2\alpha} - \frac{1+3\alpha}{(1+2\alpha)^2}\right\} \tag{6}$$

Since Klein-Nishina atomic cross-sections are obtained by multiplying electronic cross-sections with charge number Z of each element that is $\sigma_a = Z.\sigma_e$. where $r_e = 2.818\ fm$ is the classical electron radius, Z is the nuclear charge of the target molecule and $\alpha = \frac{E}{m_e c^2} = \frac{hf}{0.511MeV}$ (Knoll, 1989) [17]. Also the MAC and the total cross section per atom (σ_{tot}) is related as,

$$\frac{\mu}{\rho} = \sigma_{tot}\left(\frac{N_A}{m}\right) \tag{7}$$

Here, N_A is Avogadro's number and M is the atomic weight. In addition, equation (7) and (6) shows that MAC and cross section is directly proportional. Therefore these two relation help to determine the size of tumor for treatment of cancer cell.

4. Results and Discussion

4.1 Mass attenuation coefficient of pure elements

Mass attenuation coefficient (MAC) with incidence energy of photon goes decrees for Ruthenium (Ru) with atomic number 44, Gold (Au) with atomic number 79, Bismuth (Bi) with atomic number 83, and Gadolinium (Gd) with atomic number 64 in figure 1. The MAC of Ru and Au are closed, while Bi and Gd are different from others with lower MAC. Since MAC is a measure of the probability of the interaction that occurs between incident photons and the matter of the unit mass per unit area. The interaction process occurs with incidence photon energy as the photoelectric effect and Compton because of energy limitation. For photons with low energies (<0.05 megaelectron volt [MeV]) the photoelectric process dominates in tissue. At higher photon energies (0.1-10 Me V), Compton scattering is the most probable process that takes place in irradiated tissue [18]. From this energy definition of range, it is clear that the in a lower energy range photovoltaic effect is dominant and in a higher region energy Compton effect is dominant. The MCA in the lower region of energy is higher and sharply decreases because of photoionization (photoelectric effect). In addition, MAC is directly related to the total cross-section area therefore the cross-section area also goes decrease. A decrease in cross-section with increasing the energy of photon indicates the probability of ejecting the inner electron of the atom and gives more and more information related to the inner system of an atom or consider element/compound/alloy.

When this element (Ru, Au, Bi and Gd) solution is used in Chemotherapy (as radiation therapy) for cancer treatment as antigens and radiation with different energy is incidence on cancer-loaded cells. The photoelectric effect seems to be more dominant at a lower energy of incidence photon and with higher energy photon Compton effect takes place. The emitted electron by the photoelectric effect becomes free from the target atom and carry the reaming energy of the incidence photon. With the remaining energy of the photon, photoelectric electrons (electrons emitted by the photoelectric effect) penetrate to the surrounding of the target (chemo-material/anticancer agent; loaded in the cancer cell) and kill the cancer cell. Since MAC determines the absorption and cross-section area of scattering particles (photon, electron and

ions: chemo-materials). Therefore, for big size cancer cell photoelectric effect is best than Compton effect and for small size cancer cell Compton effect is best than photoelectric effect. This is because the energy carried by photoelectrons is higher and can penetrate for longer from target and kill the cancer cell for larger area around the target and additionally the free electron is also supported by Compton effect to bust the energy of the photoelectron. In the case of the Compton effect, the bounded electron of the anticancer agent get to interact with the higher incidence energy of the photon and transforms some energy to the electron-bounded electron and then goes aways (after interaction/scattering) and the energy of the photon after scattering is low and can't get the transfer for longer distance and hence can kill only the cancer nearby target (chemo-material). Therefore, for larger cancer cell the cell should be loaded with the anticancer agent (Ru and Au) while for small size cancer cell Bi and Gd are best. The size of a cancer cell is the limitation of this work.

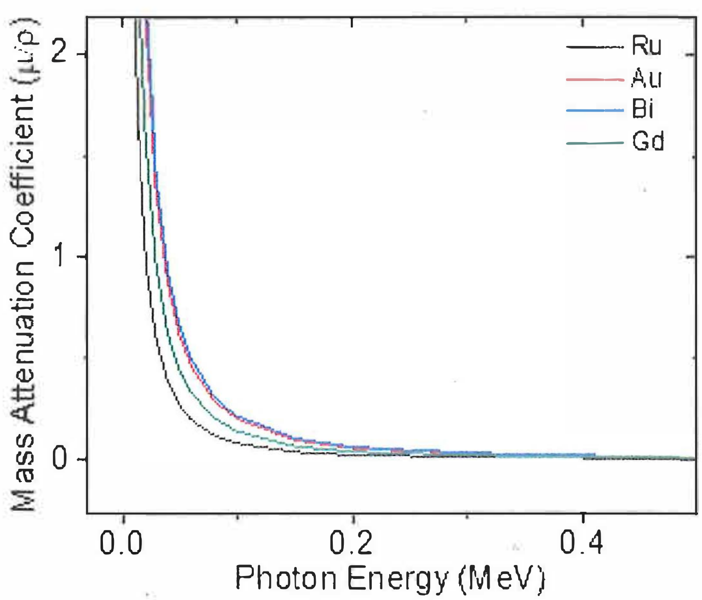

Figure 1: MAC with incidence energy of Photon

4.2 Mass attenuation coefficient of oxides

MAC of corresponding possible oxide (Ru, Au, BI and Gd) with incidence photon energy is shown in figure 2. The nature is similar to MAC of elements/atoms but MAC is different from elements. The MAC of considered oxide of anticancer agents and the phenomenon of interaction is described in

the above section with figure 1. The MAC of $RuO_2 < Gd_2O_3 < BiGdO_5Ru < BiGdO_3 < Au_2O_3 < Bi_2O_3$ increasing order, since the cross-section area is directly proportional to the MAC. Therefore, the cross-section area of scattering is also of $RuO_2 < Gd_2O_3 < BiGdO_5Ru < BiGdO_3 < Au_2O_3 < Bi_2O_3$ increasing order. In the selection of chemo-materials prepared from oxide on the basis of cross-section and scattering (photoelectric and Compton), the chemo-material loaded to cancer cells for the small tumors is RuO_2 and the larger tumor is Bi_2O_3. This is because, on the basis of cross-section area, one determines the penetration of photoelectrons and Compton phenomena. As the linear and mass attenuation coefficients decrease with the increase of the photon beam energy of all the compositions. These are due to the Compton and electrophonic phenomena which produced the main reactions in that region [19].

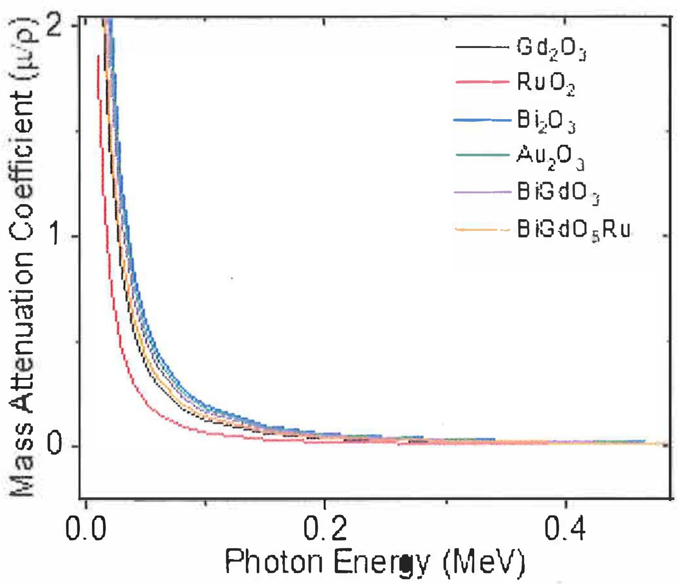

Figure 2: MAC of anticancer oxides

4.3 Mass attenuation coefficient of alloys

The MAC of alloys of anticancer agents prepared from considered anticancer agents is represented in figure 3. The alloy of Bi and Ru is prepared by mixing 0.53% by the weight of Bi with 0.47% by the weight of Ru, and alloys of Gd and Bi are prepared by mixing 0.75% by the weight of Gd with 0.25% by the weight Bi and alloys of Gd and Au is prepared by mixing of 0.55% by weight of Gd with 0.45% by weight Au. The MAC with alloys is of

Bi&Ru<Gd&Bi<Gd&Au of increasing order. Since the cross-section area is directly proportional to MAC therefore the cross-section is of Bi&Ru<Gd&Bi<Gd&Au of increasing order. Therefore, for low-sized tumors Bi %Ru is the best anticancer agent for chemo-material while for large is Gd&Au. The chemical composition by weight percentage also affects the MAC of the chemo-material. So, this chemical composition by weight help to select the anticancer agent (chemo-material) for suitable scattering (either photoelectric or Compton scattering). By chemical composition, we can determine the scattering which chemotherapy, because chemical composition determines the scattering region. So, for large cancer tumor cells photoelectric effect is dominant and hence the chemical selection material with higher atomic weight is best. But for smaller size lower concentration is best.

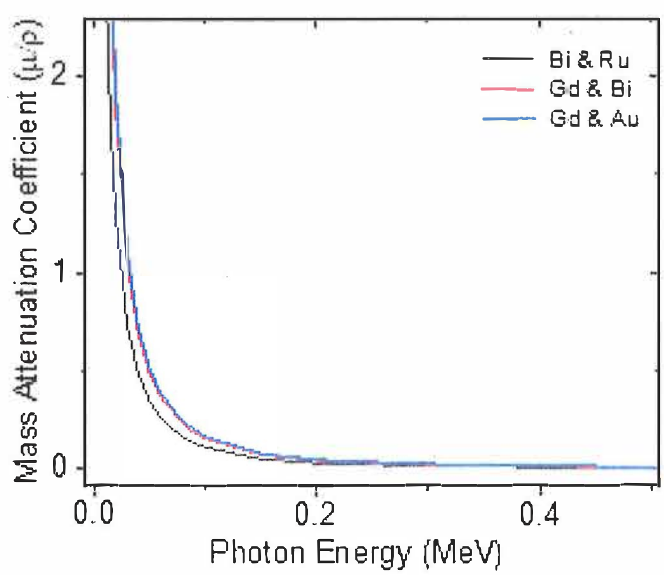

Figure 3: MAC of alloy with incidence energy of photon

On comparison of MAC of considered elements, oxides, and alloys it was found that MAC is different for the same incidence energy of the photon. In alloy, the MAC of Bi&Ru is lower while Gd&Au is higher, in oxides MAC of RuO_2 is lower and Bi_2O_3 is higher while in Ru is lower and Bi is higher. The linear and MAC of the composite substrate were studied [20]. The material was selected as a base material filled with bentonite material as a reinforced substance. The results showed an increase in gamma absorption spectrometry with thickness and thickness equivalent. Also, they showed an inverse relationship between linear and MAC with gamma ray generating

energies. The increase of the molecular weight of the filler increased linear with mass attenuation coefficients.

5. Conclusion

From the observation of Ruthenium (Ru), Gold (Au), Bismuth (Bi) and Gadolinium (Gd), and its oxides and mixture was found that the MAC decreases with increase in incidence energy of photon. The decreasing of MAC in lower energy is high while decrease in MAC was found lower with increasing incident energy of photon. Since cross section is directly proportional to MAC so the nature of cross section with incidence energy of photon is same as MAC with incidence photon. The selection of best MAC helps to determine the best cross section area and best cross section help to identify the which scattering is best for what size. Example small cross section is suitable for small cancer cell cluster treatment while larger is for larger cluser of cancer cell.

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EXTENDED SUPERSTRING AND UNIFICATION OF FOUR INTERACTIONS

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Abstract

First, the string and superstring are introduced. Next, some theories on particle physics are researched. Third, we propose the emergence string, which may derive the mass formulas of particles, etc. We study the extended superstring, which as a beautiful mathematical tool may be applied widely. Fourth, the unification of four interactions is searched. It includes the simplified supersymmetry. Fifth, we discuss neutrinos and their oscillation, in which some problems must be researched. Finally, some aspects of particle physics are discussed. String and superstring are the important method in physics.

Key words: particle physics, string, superstring, interaction, supersymmetry, neutrino

I. String and Superstring

In order to explain success of quark model, but free quarks are not found, physicists proposed many models on quark confined, in which a famous model is string. It is proposed by Nambu and Nielson, et al., in 1969 based on the excited spectrum of double resonance on hadrons like string mathematically, all hadrons are the excited states of the fundamental entity string. Assume that the endpoint of the string is quark, so free quarks not exist. However, to overcome the ghost, space-time must be 10 or even 26 dimensions. The superstring as string is shown by the supersymmetry at high energy. The superstring is related to the differential topology.

In 1974 T. Yoneya, J. Schwarz, J. Scherk found independently that the low energy limit of string theory is the gauge theory of spin 1 and general relativity of spin 2, hence string may be a theory of quantum gravity, and a theory unifying gravity and other interactions. Now it has been found that a class of gauge theories can be regarded as string theory. Quark confinement in QCD can be considered due to the quark being pulled by the string formed by gluons, which is a way of quark confinement. The boundary condition for open string is that the normal derivative of the endpoint of string is zero, i.e., the Neumann boundary condition. This corresponds to requiring the endpoint of the string to move at the speed of light, so static string is impossible, at least it turns, and its lowest excitation state is the photon. In 1987, Green, Schwarz and Witten published book *Superstring Theory* [1].

Since 1994, solitons as solutions to the field equations have been central in string theory. Almost all objects, including the string, can be considered as solitons. At this point, in particular cases, as in the kink solution case, the Fermi number is even 1/2. In 1995 A. Strominger found the result of N. Seiberg-E. Witten in 1994, which can be used to explain the phase transitions between spaces with different topologies in the superstring. Such it may link completely different "vacuum" states. He used a particular soliton, a three-dimensional membrane.

In 1995, Witten incorporates 11-dimensional supergravity into string theory [2]. He shows that the mass is inversely proportional to the proportional coefficient of the charge and the coupling constant of the string, while the charge is independent of the coupling constant, and so the mass is inversely proportional to the coupling constant.

In 1995, J. Polchinski calculated for open string to illustrate some kind of dual on open string/closed string, and the ultraviolet in open string corresponds to the infrared in closed string, namely the later infrared/UV correspondence. Meanwhile, the classical interactions in closed string give the quantum effects in open string. Open string is dual to a closed string, s-t channel is dual, and a single circle graph with open string can be interpreted

as a tree plot with closed string. Almost all current strong-weak duals have supersymmetry [3].

Strings, especially superstrings, have great complexity, and also produce great arbitrariness. The cosmology has many metastable states, even no less than 10^{120}.

Smolin discussed three roads to quantum gravity: thermodynamics of black hole, the loop quantum gravity and the string theory [4]. High dimensions correspond to strong gravitation [4], and conversely, strong interactions are only high-dimensional gravity, such that gravitational interactions and strong interactions unify at high dimensions [5], namely three dimensions are gravitational interactions, and high dimensions corresponds to strong interactions, and small hidden space-time. String predicts the origin of the Big Bang and multiple universes.

If the Planck length becomes smaller than [4], the Planck time will also become larger accordingly. Both Planck length and time as invariants may obtain the Three Special Relativity [4]. This is three truncations introduced three invariants, in which no smaller time than t (p). And the superstring can be related to the dark energy [4].

In the theory of loop quantum gravity, the loop is the closed string. The rings are currently the kink, connection, winding, etc., in graphs, and particles are classified as the different winding modes [4]. This combines with differential equations can become dynamic, evolutionary maps, and may apply qualitative analysis theory, all kinds of singularities, especially focus sinks can form particles, stars, black holes, etc. The advantage of the loop is the set of equations that can be used in qualitative analytical theory. While string does not form systems of equations in general. But there should be systems of equations in high-dimensional space-time.

The lowest order vibration mode of open string corresponds to the photon s=1. The lowest order vibration mode of closed string corresponds to the graviton s=2. String theory has already the Feynman diagram.

Now string and superstring are the forefront and hot topics of theoretical physics [6]. This may product the Veneziano amplitude and the Regge pole, etc. Features of the superstring include: 1) higher (as 10) dimensions. 2) chirality due to rotation. 3) supersymmetry group SO(32), E(8)×E(8), O(16)×O(16). 4) non-divergence. 5) few free parameters, only string tension T, gauge coupling parameter g, and gravitational coupling parameter K, and K~ g^2T. 6) only single interaction, i.e., the string connected or disconnected. Continuous symmetry breaking derives the four interactions. 7) S-duality, T-duality, U-duality, etc., in which T-duality indicates a symmetry for the space size $R \to \alpha'/R$. The 10-dimensional superstring motion with time is namely 11 dimensions, and corresponds to 11-dimensional supergravity. 11-4=7,

Witten shows that the minimum dimension of a compact manifold having is 7 dimensions. If this corresponds to the particles, it may be quarks u,d,s and leptons v,e, μ and photon γ, or u,d,e(u,e,v) and their anti-particles (or supersymmetric particles) add single γ.

We proposed the velocity of light along the surface of a reel space in the higher-dimensional microscopic theory. In this case the velocity of light is not only variable, but also quantized on every side [7]. Further, if all 3 dimensions are extended to tubes, it will add 3 radii r, space will be 6 dimensions; if 3 dimensions are all spiral tubes, we should add 3 thread pitches h, then the space is 9 dimensions. The extra time is namely 10 dimensions.

2. Some Research of Particle Physics

In 1963 Newman-Unti-Tamburino derived the NUT solution in general relativity, which allow time travel, turn 360 degrees up stairs into the leaves at different levels of space-time.

Hiscock, et al., examined how quantization of matter fields might affect a particularly interesting subset of quasiregular: the "Taub-NUT-type" singularities [8]. These singularities are characterized by incomplete geodesics which spiral an infinite number of times around a topologically closed spatial dimension in a finite proper time, to end on one of a pair of null Cauchy horizons. In two-dimensional form ($x_2=x_3$ =const), the coordinate transformation is:

$$y_0 = t\cosh x_1,\ y_1 = t\sinh x_1. \quad (1)$$

They calculated the energy-momentum tensor for an untwisted scalar field on the closed Misner universe with three-torus topology ($T^3 \times R^1$). In this case, the points identified are:

$$x_1(t,x_1,x_2,x_3) \leftrightarrow (t,x_1+na,x_2+mb,x_3+lc). \quad (2)$$

There are additional terms in the stress energy caused by the imposition of periodic boundary conditions in the x_2 and x_3 directions. This approach is more fundamental than the classical stability analyses.

In asymptotically (A)dS/flat space-times with NUT charge there is an additional periodicity constraint for t that arises from demanding the absence of Misner-string singularities. When matched with the periodicity β, this yields an additional consistency criterion that relates the mass and NUT parameters, the solutions of which produce generalizations of asymptotically flat Taub-bolt/NUT can classified by the asymptotically (A)dS case.

Mann, et al., considered the spherical Taub-NUT-dS solution [9], which is constructed as a circle fibration over the sphere in de Sitter background:

$$ds^2 = V(\tau)(dt + 2n\cos\theta d\phi)^2 - \frac{d\tau^2}{V(\tau)} + (\tau^2 + n^2)(d\theta^2 + \sin^2\theta d\phi^2), \quad (3)$$

where $V(\tau) = \dfrac{\tau^4 + (6n^2 - l^2)\tau^2 + 2ml^2\tau - n^2(3n^2 - l^2)}{(\tau^2 + n^2)l^2}$, (4)

and obtain mass

$$m = m_c = -\frac{\tau_c^4 - (6n^2 + l^2)\tau_c^2 - N^2(3n^2 + l^2)}{2l^2\tau_c}. \quad (5)$$

The metric of the Taub-NUT AdS solution in four dimensions:

$$ds^2 = -V(r)(dt - 2n\cos\theta d\phi)^2 + \frac{dr^2}{V(r)} + (r^2 + n^2)(d\theta^2 + \sin^2\theta d\phi^2), \quad (6)$$

where $V(r) = \dfrac{r^4 + (6n^2 + l^2)r^2 + 2ml^2r - n^2(3n^2 + l^2)}{(r^2 + n^2)l^2}$. (7)

Removal of the Misner-string singularities leads us to periodically identify the coordinate T with period $8\pi N / q$, where q is a non-negative integer.

In 1998 Santilli shown that the objections against the Einstein-Podolsky-Rosen (EPR) argument are valid for point-like particles in vacuum (*exterior dynamical systems*), but the same objections are inapplicable (rather than being violated) for extended particles within hyperdense physical media (*interior dynamical systems*) because the latter systems appear to admit an identical classical counterpart when treated with the isotopic branch of hadronic mathematics and mechanics. Now Santilli reviewed, upgraded and specialized the basic mathematical, physical and chemical methods for the study of the EPR prediction that quantum mechanics is not a complete theory. This includes basic methods [10], apparent proof of the EPR argument [11], and examples and applications, in which the validity of the EPR final statement is the effect that the wavefunction of quantum mechanics does not provide a complete description of the physical reality. The axiom-preserving "completion" of the quantum mechanical wavefunction due to deep wave-overlapping when represented via isomathematics, and shown that it permits an otherwise impossible representation of the attractive force between identical electrons pairs in valence coupling, as well as the representation of *all* characteristics of various physical and chemical systems existing in nature [12]. Moreover, Santill studied the classical determinism of EPR prediction by isomathematics [13].

From the EPR prediction, the nonlocality and entangled state become the frontline in modern physics. Based on the generalized Lorentz transformation (GLT) with superluminal in the complete special relativity [14,7], we proposed that the entangled states must obey GLT because they possess the

superluminal and some characters as the spacelike vectors. Further, it changes the phase of the entangled field, whose phase particle (phason) has some characters and corresponding equations. It is tachyon, and assume that it is similar to photon and J=1 and m=0 or mass is very small as similar neutrino, and may show the action at a distance. We researched that this field as wave has some characters [15]. We discussed the superluminal quantum communication by a pair of entangled states is generated on both positions, or by preparing and transmitting a pair of entangled instruments, so the superluminal quantum communication [15-17]. Manipulation for one position can pass the same message or information to the other, so we may implement the superluminal communication. Assume that the entangled field has a similar magnetic theory, which may be a quantum cosmic field, or be the extensive quantum theory, or God or the Buddha-fields and so on. These are all macroscopic fields, which correspond to de Broglie-Bohm nonlinear "hidden variable" theory, but it is microscopic [15]. In a word, study and application of nonlocality and entangled field have important scientific and social significance [15-17].

The length of the string is directly proportion the wavelength. String unifies wave-particle duality. It has energy-momentum and frequency-wavelength. Long waves correspond particularly clearly to fluctuations, while at small space-time and high energy a segment of string or it changes smaller, which shows hardly wave [14]. By relativity, the string is shortened at high speed. The string obeys the wave equation. For dynamic, high energy it constantly breaks into multiple bars and multiple quarks, and corresponds to the multiparticle production. Point particles are easier to show particle properties; string similar generalized objects, is not wave. Hadronic string contracted to point has tension and massless. It with tension corresponds to the Heisenberg self-interaction, and has length, and obtains mass. This is a point at low energy and a string at high energy. The scale of string is:

$$L_p = (G\hbar / c^3)^{1/2} \approx 10^{-33}\,\text{cm}, \quad L_p / L_{proton} = 10^{-20} \approx L_{atom} / L_{sun}. \quad (8)$$

So far the high energy experiments in the past sixty years have shown that the smallest mass fermions are proton, electron, neutrino and photon, which form the simplest model of particles. These fermions seem to be inseparable truth "atoms" (elements), because further experiments derive particles with bigger mass. They correspond to four interactions, and are also only stable particles. Such the final simplest theory is based on leptons (e-ν_e) and nucleons (p-n) or (u-d) in quark model with SU(2) symmetry and corresponding Yang-Mills (Y-M) field. Other particles and quark-lepton are their excited states. Their spectrum is mass formula and symmetric lifetime formula. Some applications are discussed. Further, the simplest interactions and unification of weak-strong interactions by QCD are searched. We research opposite

continuous separable models. Further, we proposed some possibly developed directions of particle physics, for example, violation of basic principles, in particular, the uncertainty principle, and precision and systematization of the simplest model, etc [18].

The spin-line velocity of superstring is $\omega(l/2)=c$, the potential energy $E=2lm_0$ is proportional to the length. The angular momentum is $M \propto E^2$. It is similar to the harmonic oscillator, and relates to the Regge trajectory, and is the development of dynamic integrators Veneziano model. The ground state mass of string is determined by the intercept constant in the Regge formula, the mass is proportional to the tension of string, the intercept is a function of the space-time dimension, usually is negative, so the mass square of the ground state of Bose string is negative, i.e., tachyon.

At present, Bagchi, et al., reconsider the tensionless limit on bosonic closed string theory, and tensionless path from closed to open strings [19]. Kaidi, et al., pointed out the classification of string theories via topological phases, and discussed the relationship between it and the K-theoretic classification of D-branes [20]. Costello, et al., discussed Chern-Simons Origin of Superstring Integrability [21]. Geyer, et al., proposed a procedure to determine the moduli-space integrands of loop-level superstring amplitudes for massless external states in terms of the field theory limit [22].

In quark-string model, the endpoints of string indicate the quark particles. Such mesons are composed of two quarks, and are unstable, corresponding string is not closed, and must be open string. Baryons are composed of three quarks, and can be closed string, such as ○, which can be stable. If it is developed as a multiple closure of concentric circles, this will correspond to an increase in the new quantum numbers S, C, etc. They are excited states with different radius.

The string theory is not problem in dotted model. The superstring uses an elliptic modular function, and corresponds to the B function and the Veneziano model. But it could not even get approximate particle mass spectrum like the earlier string model.

Guillen, et al., present a new method to explicitly compute string tree-level amplitudes involving one massive state and any number of massless ones. In this simplified model, they determined scattering massive string resonances through field-theory methods [23].

3. Emergence String, Extended Superstring and Their Applications

The string equation is developed to the wave equation, and corresponds to the oscillation- rotation model (ORM) [14] developed to the dynamical model. The emergence string just as the emergence particles behave as macroscopic phonons. S-duality of strong and weak interactions may correspond to string and particles, and according to Yukawa interaction and uncertainty principle, it

can turn into a scale duality, so the scale of string can be amplified. Early string is not diverge, and contains gravitons (J=2), D=26, and appears tachyon. New superstring has not tachyon, D=10, and eliminates anomaly.

Based on two moving states of the emergence string: oscillation and rotation, we derived its quantum potential and the equation, whose energy spectrum is the GMO mass formula and its modified accurate mass formula [24,14]:

$$M = M_0 + AS + B[I(I+1) - S^2/2]. \qquad (9)$$

These are some relations between the string and observable experimental data. Further, based on the Y-Q and I-U symmetries between mass and lifetime on the general SU(3) theory, we can derive the lifetime formulas of hyperons and mesons:

$$\tau = A[2U(U+1) - Q/2], \qquad (10)$$

and $$\tau = A'[(1/2) + 2U(U+1) - Q/2 - Q^2/3]. \qquad (11)$$

They agree better with experiments. It is a new method on lifetime of hadrons described by quantum numbers. They are symmetrical with the corresponding mass formulas, and can be unified for mass and lifetime. These formulas may also extend to describe masses and lifetime of heavy flavor hadrons [24-26].

The emergence strings of different levels can produce different strings. We may explain various macroscopic phenomena by the emergence string and the general extended string.

The Regge theory S=aJ+b, parity of mesons and baryons are positive and negative intersects. N and △ also intersects appear. It constantly increases vector mesons and spins, and J^P change accordingly, and unify various hadrons and their resonances.

It is possibly related to some new extensive fields from complex number fields, in which matrices of 2m+1 and 2m+2 rank may have 4m elements.

The graph theory has already many applications [27]. Mathematically, we proposed developments in graph theory, which include five types of the basic elements: various solid lines (E), dotted lines (D) and wavy lines (W), which correspond to the edge-induced spanning-tree in some graphs, and vertices (V), fields (F). New extensive graph may describe some phenomena in natural science and social science. In particle physics, the solid lines represent fermions, the wavy lines represent photons, the dotted line represents meson, the double solid line represents the proton [28], and so on, which are namely Feynman diagrams. Vertices correspond to leptons of non-structure, fields corresponds to hadrons with internal structures. These lines may correspond to different interactions, the Regge poles and the Regge trajectories, strings, superstrings and bags, membranes, M theories, etc.

The baryons of three quark may be described by the Borromean rings (Fig.1) [29] with three loops in topology [30], here united they stand, divided they fall.

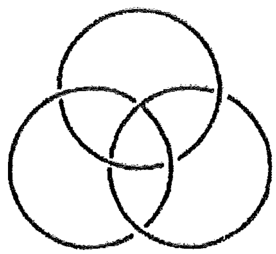

Fig. 1. Borromean rings

If we add directed, weighted and color for Borromean rings, it will be able to explain spins of particle and quarks with different masses and colors, etc.

Because the helix in three dimensional spaces and the basic formula of quantum mechanics are completely same, therefore, we proposed that the three-dimensional emergence string may form a whirlon (roton) model of particles, which may describe visually the basic relations of quantum mechanics [31]. The quark-leptons of different generations possibly correspond to whirlons with increasing helicity. This can be related to neutrinos as it particularly vividly describes neutrinos, and corresponds to parity nonconserved.

This may be related to the circle number of in topology. In 1990s the duality of superstring can be derived from the dual radius, whose reciprocal is equal to itself. This radius is the minimum scale in string theory, and is equal to the length scaling of string.

If whirlon corresponds to the particle spin, ν^{-1}=T will be the time required for a particle to rotate for one circle. The smaller the cycle T is, the greater the frequency, the faster, the higher the energy. Both superstring and whirlon are very geometrical [31].

The rotating string is 10-dimensional, and the lowest state of string is the tachyon. The string model shows that quarks are symmetric and dual resonances, which probably do not actually exist.

The whirlon corresponds to vector with both size and pitch, and vector is at four dimension macroscopic space-time. Whorl is also one of the eight treasures of Buddhism. It means that the Dharma sound of the Buddha is widely melodious, as far as the vast world.

Generally, the spiral motion is one of the basic motions for various macroscopic changes. It is described from Descartes to the helix motion in magnetic field, and pulsar and the spiral galaxies in astronomy. The

superstring (whirlon) is the most fundamental structural basis of the microworld. It is the result of a spatial curl with reduced dimension.

Now the N=4 supersymmetric Y-M theory is widely studied. Jiang, et al. discussed its planar exact three-point functions of determinant operators based on the gauge-string duality, and the proposal is put to the test at weak coupling [32]. Dorigoni, et al., obtained the novel representation of an integrated correlator in the SU(N) theory [33]. Gaberdiel, et al., proposed a description of worldsheet theory as a natural generalization of the tensionless string [34].

We discuss the like magnetic field and electromagnetic field of mesons. This can be quantized, and the general relativity is geometrical. Its energy levels combine string theory and integers and fractional Hell effects, etc. Assume that the quarks are connected by string, which is again the QCD and the gauge field, then the non-Abel fields and the QCD may lead to the string or like string. This string elongation requires force and energy, which determine the mass is proportional to length *l*, which is finite about 10^{-13} cm, and a finite range of action. Longer length corresponds to larger m, and easy to decay. They are pull fracture, i.e., different particles. QCD $\Leftrightarrow$ string=particles, both pay equal attention for the hypothesis of duality. Two different theories (e. g., weak and strong interactions) are equivalent. This is the development of the field and the particle. Wave-particle duality is its special example. Such a so different superstring theory will be a different manifestation of a larger theory. The M theory is namely a developed superstring theory. Further, superstring can be developed into a Yin-Yang double helix structure.

For a large class of black holes that can be implemented in string, string theory can in principle solve all quantum problems associated with black holes. Although the quantum physics of the most universal and simplest Schwarzschild black holes is not currently understood in string theory. The string theory shows that black holes, like any other thermodynamic system, obey quantum mechanics, and the entropy of black holes is also a measure of the number of microscopic states. The black hole string ranges from minimal to maximal, extremely heavy, i.e., the cosmic string. For the extremal black hole of string theory, there have charge and mass in 4 dimensions, and the charge reaches the maximum allowed. However, the temperature is near zero, about 10^{-7} K, and the entropy is not zero. In 1994, L. Susskind proposed a principle that any quantum system containing gravity satisfies the holography principle. Many physicists think always that in the quantum gravity theory, classical geometry should be replaced by similar concepts of noncommutation geometry, but which is not specific model.

The cosmic string is a huge emergence string, and is also an extended string. The string may have oscillation, rotation and twist, which corresponds to the torsion.

The string model must be high-dimensional. This is a one-dimensional space model, and may be developed into two and three dimensions, i.e., the brane model and the bag model. The latter is visually similar to the fireball and droplet model. The string is developed to a superstring model, which corresponds to have super-brane and super-bag models. The super-brane is an expansion of the superstring theory, and is a high-dimensional supersymmetric extension, i.e., the supersymmetric p-brane, and p=1 is the superstring. The quantization of string is only allowed if d=26 (boson string) or 10 (superstring) dimensions. Based on the cavity QED [35], we may research the cavity QCD, and combine the super-brane, etc. Further, we propose the tube-pipe particles, tube space and time, and tube physics, etc. Its difference with the string is that interior is empty. It corresponds to the bag.

The superstring has a supersymmetry. But it is minimal, so it may correspond to statistics. Further, the statistical properties of the superstring can be investigated. Its statistics should be linked to various statistical models. These are the possible big directions of superstring. The string model is phenomenal and more mathematical. Perhaps superstring should combine kinetics. Otherwise, superstring may only be a beautiful mathematical tool.

The problem of superstring may be in a high-dimensional space. The way out of high-dimensional space is probably that there are only new quantum space-time with micro small strength. Or appear in the multi-world, the negative matter [36-42] and the Yin-Yang world. Latter both are dual space-time. There has string, then the opposite string and the negative string and the negative opposite string may exist.

Santilli reviewed and upgraded the iso-representation of the spin 1/2 of nucleons according to the isotopic branch of hadronic mechanics, and is consistent with the spin J=1 and the magnetic moment of the Deuteron with the numeric value λ=2.65557 of Bohm hidden variable [43]. We researched some further possible directions of experiments. Based on the known mass and lifetime formulas and three generation hadrons, we studied differences on the electromagnetic mass of baryons and mesons, and their results are calculated for some hadrons [44].

Some structures in biology are helix. RNA is a single link structure on A-U and G-C. Here A is adenine and G is guanine, while U is uracil and C is cytosine. It is known that a helical line is:

$$x = a\cos t, y = b\sin t, z = dt. \qquad (12)$$

Here d is pitch. A form of the complex function is $z = a\cos t + ib\sin t$, $w = dt$. The double helix is:

$$z = a\cos(\varphi + \frac{C_1}{C_2}) \text{ and } w = d\varphi. \quad (13)$$

The whirlon [31] can combine the focus (source and sink). Radius a(t)=b(t)=$a_0 - 1$. a= a_0 for t=0; a=0 for t=1.

Based on the extensive quantum biology, we derived the double helical structure of DNA from Schrödinger equation, in which the basic quantum elements are A-T and G-C [45-47]. It is necessity mathematical conclusion that quantum mechanics has symmetry. Further, we researched the biological string [45], and string-brane theory and Calabi-Yau manifolds in biology [48].

4. Unification of Four Interactions, and Simplified Supersymmetry

For superstring, it first must study carefully that how it constitutes multiple particles and determines their different masses, namely, the relations of superstring and structure is a complex subject. Second, whether or not it still similar to the Yukawa interaction with exchange particles each other, or have already developed? Its theory is QCD, but whether or not should develop? This can be related to the development of weak interactions, etc. Although theoretically superstring passes through symmetry groups have already been connected to the unity of interactions.

Superstring may form the higher dimensional space. We assume that in 10-dimensional theory, 3 dimensional is gravitational field, and plus time is 4 dimensional general relativity; 1 dimensional is electromagnetic field. Both are the macroscopic fields. While the remaining 5 dimensions are microscopic fields, 3 dimension is strong field, and corresponds to SU(3); 2 dimension is weak field, and corresponds to SU(2). Such a microscopic space-time is 10 dimensions, and a macroscopic space-time is 4 or 5 dimension.

Group U(1) corresponds to electromagnetic interactions, (e,v) are electromagnetic and weak interactions, respectively. For m=0, they are Proca and Wely equations. QED has reached extremely high accuracy with perturbation. In atoms, especially hydrogen; in the nucleus it should be hydrogen, deuterium, tritium.

For the unified four interactions, the key is the unification of quantum theory and general relativity. This is also a dreams of final theory as the scientist's search for the ultimate law of nature [49].

From general relativity to quantum theory is the quantization and operators of the space-time quantity $G_{\mu\nu}$ and the matter quantity $T_{\mu\nu}$ in

$$G_{\mu\nu}\psi = aT_{\mu\nu}\psi . \quad (14)$$

We proposed possible equations unified between general relativity and quantum theory:

$$(\hat{G}_{kl} + \Lambda\hat{g}_{kl})\psi = k\hat{T}_{kl}\psi = \lambda_{kl}\psi , \quad (15)$$

Here λ_{kl} are eigenvalue of matrix. General case $\hat{R}_{kl},\hat{T}_{kl}$ are operators. Therefore, 1) When they are simplified, theory should derive quantum mechanics and various corresponding equations. 2) They are not operator, theory becomes general relativity. 3) Microscopic wave property produces the wave function, in particular, it may express the microscopic gravitational field. 4) According to the correspondence principle, fourth dimension of tensor T is namely four dimensional momentum. 5) Probably operator is:

$$\psi = A\exp(iR_{\mu\nu}g_{\mu\nu}/\hbar), \tag{16}$$

or

$$A\exp(iT_{\mu\nu}x_{\mu}x_{\nu}/\hbar), \tag{17}$$

therefore,

$$R_{\mu\nu} = i\hbar(\partial/\partial g_{\mu\nu}). \tag{18}$$

They combine usual quantization method of gravitational field, etc. 6) $\hat{R}_{kl}\psi = 0$ should be graviton equation [50,51].

From quantum theory to general relativity is a quantum theory in curved space-time. If gravity is only space-time curved, then the curved unification of space-time is the unified theory of four interactions, i.e., Eqs.(14).

In the quantum cosmic field the wave function of Universe obeys the Wheeler-de Witt equation:

$$(\hbar^2 G_{ijkl}\frac{\delta}{\delta g_{ij}}\frac{\delta}{\delta g_{kl}} + \sqrt{G^3}R)\psi(g) = 0. \tag{19}$$

Here $G_{ijkl} = \frac{1}{2\sqrt{G}}(g_{ik}g_{jl} + g_{il}g_{jk} - g_{ij}g_{kl})$. The equation may be developed to the nonlinear form:

$$(\hbar^2 G_{ijkl}\frac{\delta}{\delta g_{ij}}\frac{\delta}{\delta g_{kl}} + \sqrt{G^3}R - \hbar^2 G_{ijkl}\frac{1}{|u|}\frac{\delta^2 |u|}{\delta g_{ij}\delta g_{kl}})u(g) = 0. \tag{20}$$

Further, in the extensive general relativity [52] any space-time of interactions and fields is all curved. Otherwise, the gravitational field is also quantized. These are both unifications.

SU(2) corresponds to weak interaction, QFD, and I=1/2 (p,n), (u,d) is strong interaction, SU(N) and QCD, Y-M equation. This has an asymptotic freedom. The accuracy should be improved.

Strong and weak interactions as short-range should be unified. Except different action ranges their main character is: strong interactions are attraction each other, and weak interactions are mutual repulsion and derive decay. We proposed a new method on their unification, whose coupling constants are negative and positive, respectively [53,54]. For QED and QCD,

beta functions have different signs. The electroweak unification theory has the same sign with QED.

In Fig. 2 three-generation quarks of the standard model are unified into a three-dimensional space:

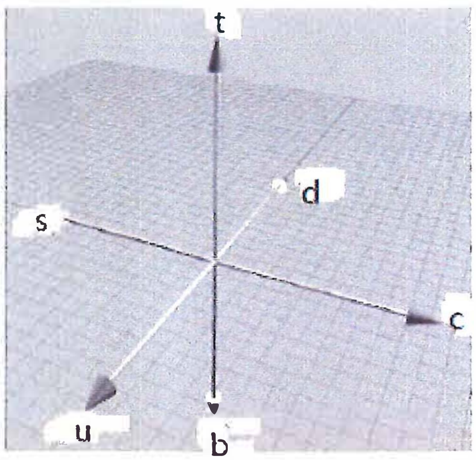

Fig. 2 three-generation quarks unified in three-dimensional space

This is developed to three-generation leptons (Fig.3):

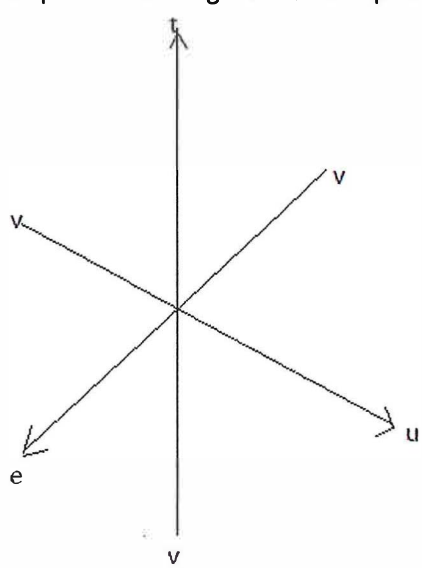

Fig. 3 three-generation leptons unified in three-dimensional space

Four interactions correspond to only four stable particles (photon, electron, neutrino ν_e and proton) [18], and four types: mass m, charge Q, lepton number and hadron number, where the baryon number is conserved, while the meson number is not conserved.

It is well-known that the theoretical base of particles is the standard model:

$$\begin{array}{cccc} q=(2/3)e & -(1/3)e & -e & 0 \\ \begin{pmatrix} u \\ c \\ t \end{pmatrix} & \begin{pmatrix} d \\ s \\ b \end{pmatrix} & \begin{pmatrix} e \\ \mu \\ \tau \end{pmatrix} & \begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} \end{array}. \qquad (21)$$

Such the second and third generations of quark-lepton are the different excited states of the first generation. The total charge number of per generation quarks is 3(2/3-1/3)=1, and the total charge number of per generation leptons is yet (-1+0)=-1. The total charge of per generation quark-lepton is 0. This is very symmetrical and beautiful theory [26].

We discussed the modified accurate mass formula, and applied to heavy flavor hadrons, and derived some predictions, m(Ω_{cc}^{+})=3950.7 or 3908*MeV*, and $m(\Xi_{bb})$=10396.8 or 10348.9*MeV*, etc. It is a quantitative and testable theory. Based on the new data, we proposed various lifetime formulas of heavy flavor hadrons, which very agree with experiments. This is a new method on lifetime of hadrons described by quantum numbers, and can be unified for mass and lifetime. Based on the known symmetrical particles and their excited states we proposed an approximate simplified supersymmetry theory, in which all bosons are the degenerate states [26].

Moreover, quarks have three generations, gluons should have three generations. Or second and third generation quarks are excited states of the first generation quarks, so the corresponding second and third generation gluons will also be the first generation excited states. This may be applied to astronomy and the universe.

5. Neutrinos, their Oscillations and New Research

In March, 2012 China Daya Bay neutrino study found that its speed is 10^{20} times less than the speed of light. This corresponds to the neutrinos having very small masses. The far 1500m electron neutrinos are 6% less than the near ones, which is usually attributed to neutrino oscillations.

If the neutrinos oscillate, then the symmetric three-generation leptons can also oscillate. Further, three generations of quarks can oscillate, possibly even with arbitrary particles.

This is more likely to the n-p oscillations in the nucleus, $n \to pe\bar{\nu}_e$ and conversely $p+e^{+} \Leftrightarrow n+\bar{\nu}_e$. $\mu \to e\nu_\mu\bar{\nu}_e$, and $\tau \to \mu\bar{\nu}_\mu\nu_\tau$.

According to the special relativity, neutrino has rest mass, so its velocity v<c. We may assume that different neutrinos have different velocities:

$$m_i = \frac{m_0}{\sqrt{1-(v_i/c)^2}}. \tag{22}$$

1) If m is the same, so $v_i = c\sqrt{1-(m_0/m_i)^2}$, larger m the larger also velocity. 2) If v is the same, so m_i is proportional to m_0. The measured velocities of different neutrinos may determine 1) or 2).

The corresponding three-generation leptons can also be discussed similarly. Conversely, the mass formula of leptons $m = m_e(1+n/\alpha)$ [14] may be applied to three generations of neutrinos. Further, this may extend to three generations of quarks.

In June, 2001 Canada SNO released scientific results of detecting all three neutrinos from the sun, and confirm that solar neutrinos convert on their way to Earth, and the total flow of the three neutrinos fits well with the predictions of the standard solar model [55].

In order to explain the "solar neutrino missing" problem, the neutrino oscillation hypothesis is proposed. This must that neutrinos have rest masses (Dirac or Majorana masses), and they should be different for three types of neutrinos ν_e, ν_μ, ν_τ, and they are linear combinations of different masses $|\nu_1>, |\nu_2>$:

$$|\nu_e> = \cos\theta|\nu_1> + \sin\theta|\nu_2>, \tag{23}$$

$$|\nu_\mu> = -\sin\theta|\nu_1> + \cos\theta|\nu_2>. \tag{24}$$

Thus, the neutrino oscillation scale is:

$$L_0 = \frac{4\pi\hbar cE}{\delta m^2 c^4}. \tag{25}$$

If the oscillation scale is about the distance between the Sun and Earth, the detection of ν_e from the Sun will be significantly reduced. If the oscillation scale is much larger than the distance between the Sun and the Earth, then the neutrino oscillation in the vacuum still cannot explain the solar neutrino disappearance. In 1998 Super K found ν_e-ν_μ oscillation, and in 2012 found ν_e-ν_τ oscillations [56].

Even if neutrinos oscillate, they cannot be missing. Neutrinos have masses, but smaller mass oscillations to larger masses do not conform to the basic energy conservation law. Unless it is a virtual oscillation, but the result is an actual neutrino missing! Or the three neutrinos have the same mass! General nuclear reactions will only produce ν_e. Only a large number of

occurrence μ,τ can produce ν_μ,ν_τ . The standard solar model is $4^1H\to{}^4He+2e^+ +2\nu_e$, and produce μ,τ and corresponding ν_μ,ν_τ.

We think that the oscillation of neutrinos with very different masses is difficult. According to the symmetry of leptons, three-generation neutrinos may not oscillate, but should be decay $\nu_\tau \to \nu_\mu \to \nu_e$, as $\tau \to \mu \to e$. Even if μ and electron e cannot oscillate, but only μ can decay to e.

Neutrino physics is not only related to lepton physics, and to a relativistic limit velocity, but also related to the Big Bang universe, dark matter and new physics [57], etc. According to the Yukawa interaction, massless neutrinos exchange with massive W-Z bosons, which is surprising. So far fourth leptons and $\tau \to \mu\gamma$ have not been discovered.

We must assume that the three lepton numbers are not conserved and change to each other. Some experiments and theories have been explored to this point. This is also related to the supersymmetric grand unified theory with family symmetry [58]. Gonzalez-Garcia and Nir discussed the phenomenon of neutrino masses and their mixing, the neutrino oscillations in vacuum and matter, and explore the existence of new physics, etc [59]. Delepine, et al., applied standard quantum field theory to calculate the CP asymmetry for neutrino oscillations and new physics, and the supersymmetry generalization of the standard model produces observable CP asymmetry in next generation neutrino experiments [60].

6. Discussion and Conclusion

For $\Omega^-(sss)$, it can assume: 1. there are three colors. 2. PEP is violated. 3. Three s quarks are in different excited states, such as 3 types of s are equidistant $m_0, m_0+\Delta, m_0+2\Delta$, so $m_0+\Delta$=557.48MeV.

In Feb. 2014, S-Kadif found electron-surrounded quantum droplets, which is similar particle with only a trillion of a second. This corresponds to high energy $\Delta E\Delta t=\hbar$, and $\Delta E=\hbar/\Delta t$, which probably violate PEP.

The strong interaction potential between the quarks changes to:

$$V=-\frac{4}{3}\frac{\alpha_s}{r}+Kr. \qquad (26)$$

For V=0, $r=\sqrt{\frac{4}{3}\frac{\alpha_s}{K}}$.

The general strong interaction potential is:

$$V=-\frac{\alpha_s}{r}+Kr. \qquad (27)$$

For V=0, $r=\sqrt{\frac{\alpha_s}{K}}\sim 10^{-13}cm$.

Fermions such as electron e can form a Cooper pair, so ee, qq, etc., may also form a pair, which correspond to bosons. If the force between fermions corresponds to weak interaction, it is also weak interaction between bosons. Furthermore, the positive and antimatter form a couple Q=0, and the positive and negative matters form a couple M=0 [36-42].

The three-color triquarks are baryons, and quark pair are mesons, both colored C=0. The color is introduced for PEP, and then is more complex gluons. The eight particles require mathematically the strongly interacting three-color SU(3), all have 0 mass and have the same strength g. Three generations of 6 quarks are beautiful, quarks can infer mass, etc. But, introduced color, 18 quarks and the corresponding theory are complexity. Three generations of three-color quarks are the SU(3)×SU(6) group. Three generations of leptons are exchanged by W-Z, and all eight particles have been found. And 18 color quarks and 8 gluons that should be the same for three generations are not found. The QCD and its ultraviolet slavery and asymptotic freedom seem just to prove that the free quark does not exist. (e, v) is the same generation I=1/2, the difference is only the electromagnetic interaction, which is similar to (p, n).

This is the spin-independent supersymmetry, e. g.

$$\begin{pmatrix} p & n \\ \pi^{\pm} & \pi^{0} \end{pmatrix} I = \begin{matrix} 1/2 \\ 1 \end{matrix}, J = \begin{matrix} 1/2 \\ 0 \end{matrix}. \qquad (28)$$

The open string is like magnetic charge, which may use the similar magnetic field theory of superstring, for motion, and string endpoint, etc. In quark-string model, this is similar to the magnetic monopole. Following the Dirac formula and its generalization $\mu e = n/2$. We can develop a like-monopole to a single quark, and obtain probably quark confinement. Further research will be the baryons of three quarks similar to the electromagnetic theory. The gluon force should be more similar to magnetic forces, without quarks correspond to no magnetic monopoles. There may be similar macroscopic closed string. Such magnetic monopoles and quarks will be simultaneously exist or absent. We can extend the magnetic monopole of Dirac theory, and obtain the fractional charge.

String is similar or as a topology, so it is difficult to describe quantitatively, but mainly a concept and mode.

Heisenberg proposed that a third constant should exist except c and h, which is probably scale r [61], and is related to string. The Planck space is

$l_P = \sqrt{\hbar G_N / c^3} = 1.616 \times 10^{-33} cm$ is too small, and it and α all are both combination constants.

In a word, from quantum mechanics to particle physics the applied mathematical methods are always a basic way. String and superstring as the new tool are very important aspect.

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